CONTINUATION OF SURFACE WATER QUALITY MONITORING TO SUPPORT THE IMPLEMENTATION OF THE LAMPASAS RIVER WATERSHED PROTECTION PLAN

Final Report
TSSWCB Project # 16-06
Prepared by Texas A&M AgriLife Research

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Acronyms

AgriLife Research	Texas A&M AgriLife Research
BRA	Brazos River Authority
CFS	Cubic feet per second
cfu/100mL	colony forming units per 100 milliliters
CRP	Clean Rivers Program
DSLP	Days since last precipitation
FM	Farm to Market
HWY	Highway
mg/L	milligram per liter
Partnership	Lampasas River Watershed Partnership
QAPP	Quality Assurance Project Plan
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute of Applied Environmental Research
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSSWCB	Texas State Soil and Water Conservation Board
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plans

Introduction

The Lampasas River watershed lies within the Brazos River Basin in Central Texas (**Error! Reference source not found.**), which drains to the Gulf of Mexico. The Lampasas River's headwaters are in eastern Mills County and it flows southeast for 75 miles, passing through Hamilton, Lampasas, Burnet and Bell counties. In Bell County the river turns northeast and is dammed five miles southwest of Belton to form Stillhouse Hollow Lake. Stillhouse Hollow Lake is the primary drinking water supply for much of the surrounding area. Although the watershed encompasses 798,375 acres across Mills, Hamilton, Coryell, Lampasas, Burnet, Bell and Williamson Counties, it is primarily a rural watershed with few urban centers. The cities of Lampasas and Kempner are wholly within the watershed boundaries, while the cities of Copperas Cove and Killeen are only partially in the watershed.

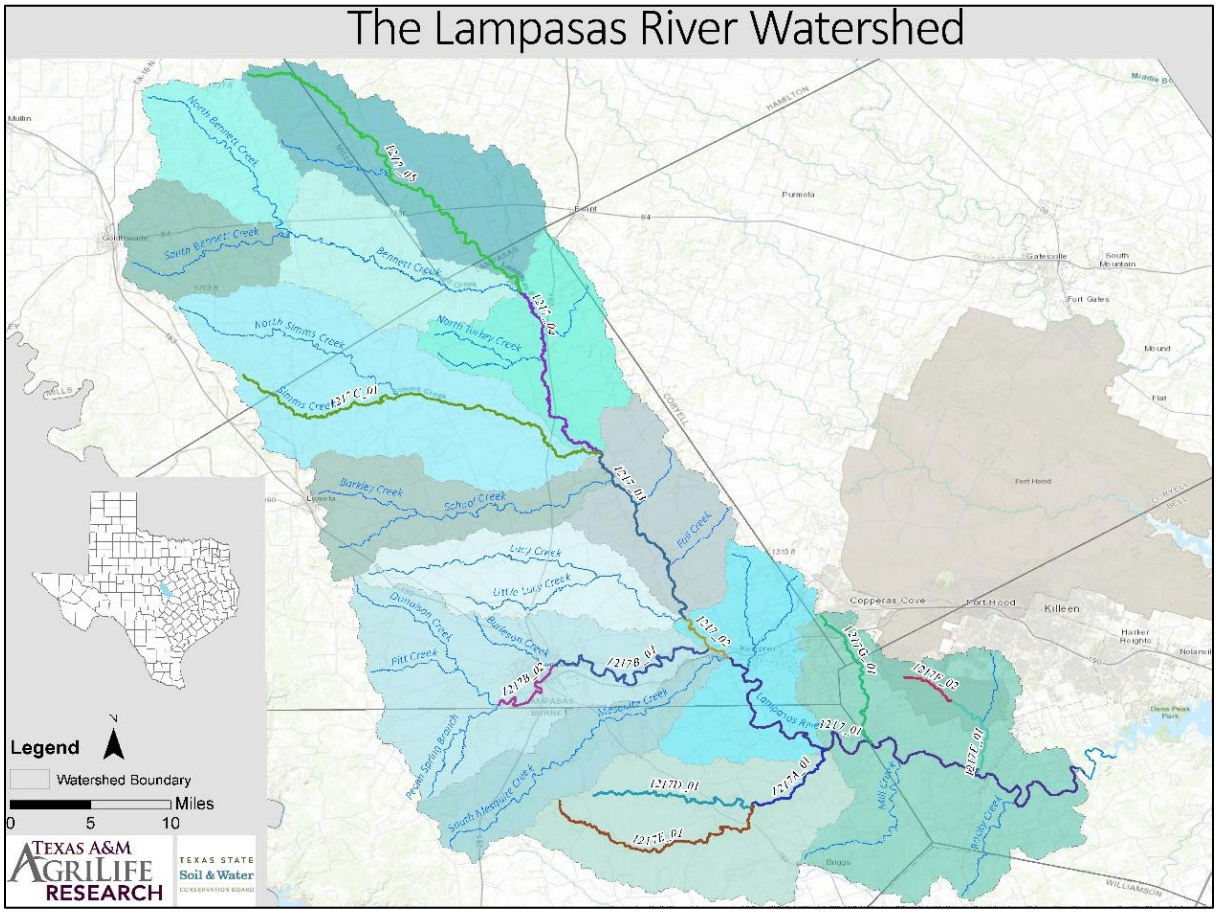


Figure 1 The Lampasas River watershed is a primarily rural watershed, located in Central Texas in the Brazos River basin.

The Lampasas River was originally listed on the 2002 303(d) List for elevated levels of bacteria and carried forward to subsequent lists in 2004, 2006 and 2008. Elevated bacteria levels are an indicator of fecal contamination from warm blooded animals and is a human health hazard. Texas A&M AgriLife Research (AgriLife Research) and Texas State Soil and Water Conservation Board (TSSWCB) established the Lampasas River Watershed Partnership (Partnership) in November 2009 as part of TSSWCB project 07-11, "*Lampasas River Watershed Assessment and Protection Project"*. The project included an updated land use analysis, modeling of historical water quality data, and the development of a Watershed Protection Plan (WPP) to address the bacteria impairment.

The development of the WPP was a stakeholder driven process facilitated by AgriLife Research. With technical assistance from AgriLife Research and other state and federal partners, the Steering Committee identified water quality issues that are of particular importance to the surrounding communities. The Steering Committee also contributed information on land uses and activities that were utilized in identifying the potential sources of bacterial impairments and in guiding the development of the WPP. The WPP identified responsible parties, implementation milestones, and estimated financial costs for individual management measures and outreach and education activities. The plan also described the estimated load reductions expected from full implementation of all management measures. In order to provide an accurate measure of the effectiveness of the WPP, the Partnership recommended an intensive water quality monitoring regime within the river and its tributaries.

Subsequent projects in the watershed have continued the implementation of the WPP, including TSSWCB project 12-09*, "Coordinating Implementation of the Lampasas River Watershed Protection Plan"*, and TSSWCB projects 14-07 and 17-05 focused on coordinating the implementation of the WPP while, TSSWCB projects 14-06 and 17-03 provided resources at the local level to Hill Country Soil and Water Conservation District to support a watershed-wide District Technician to facilitate the development of Water Quality Management Plans (WQMPs) and implementation of nonpoint source best management practices (BMP) with local landowners. AgriLife Research has also cooperated with Texas Commission on Environmental

Quality (TCEQ) to begin addressing potential failing on-site sewage systems through several projects.

It is important to note that the Lampasas River was removed from the 2010 303(d) list. The delisting of the river occurred because additional data had not been collected for assessment between 2000 and 2009; existing historical data no longer met the TCEQ criteria to be included in assessment. North Rocky Creek (Segment 1217D) was identified as impaired for depressed dissolved oxygen in 2006, however a TCEQ study conducted in 2009 showed high aquatic life. Biological data collected from North Rocky Creek indicates that it supports a relatively healthy biological community, better than that which would be expected based upon the results of the dissolved oxygen monitoring. In 2010, the TCEQ adopted revised, site-specific standards for dissolved oxygen in Rocky Creek which then received EPA approval.

Project Overview

AgriLife Research coordinated with Texas Institute of Applied Environmental Research (TIAER) to implement the recommended water quality monitoring regime which was outlined in the WPP. Historically surface water quality data was collected by the Brazos River Authority (BRA) and TCEQ through the Clean Rivers Program (CRP) on a quarterly basis.

The sampling sites were selected by the Partnership for long term sampling (Figure 2). The Partnership deemed these ten sites as "critical" for evaluating the effects of implementation. These sites were identified because they will yield a dataset that is all encompassing of areas where implementation will be focused and is spatially representative of the watershed. They felt that uninterrupted, routine, monthly monitoring would be key to providing accurate data to reflect changes within the watershed.

TIAER conducted routine ambient monitoring at ten sites monthly collecting field, conventional, flow, and bacteria parameter groups. TIAER collected monthly routine flow samples over a period of 25 months, from June 2017 through July 2019. Spatial and seasonal variations were captured across the sampling period (Table 1). The sites included 5 mainstem sites and 5 sites across 3 tributaries.

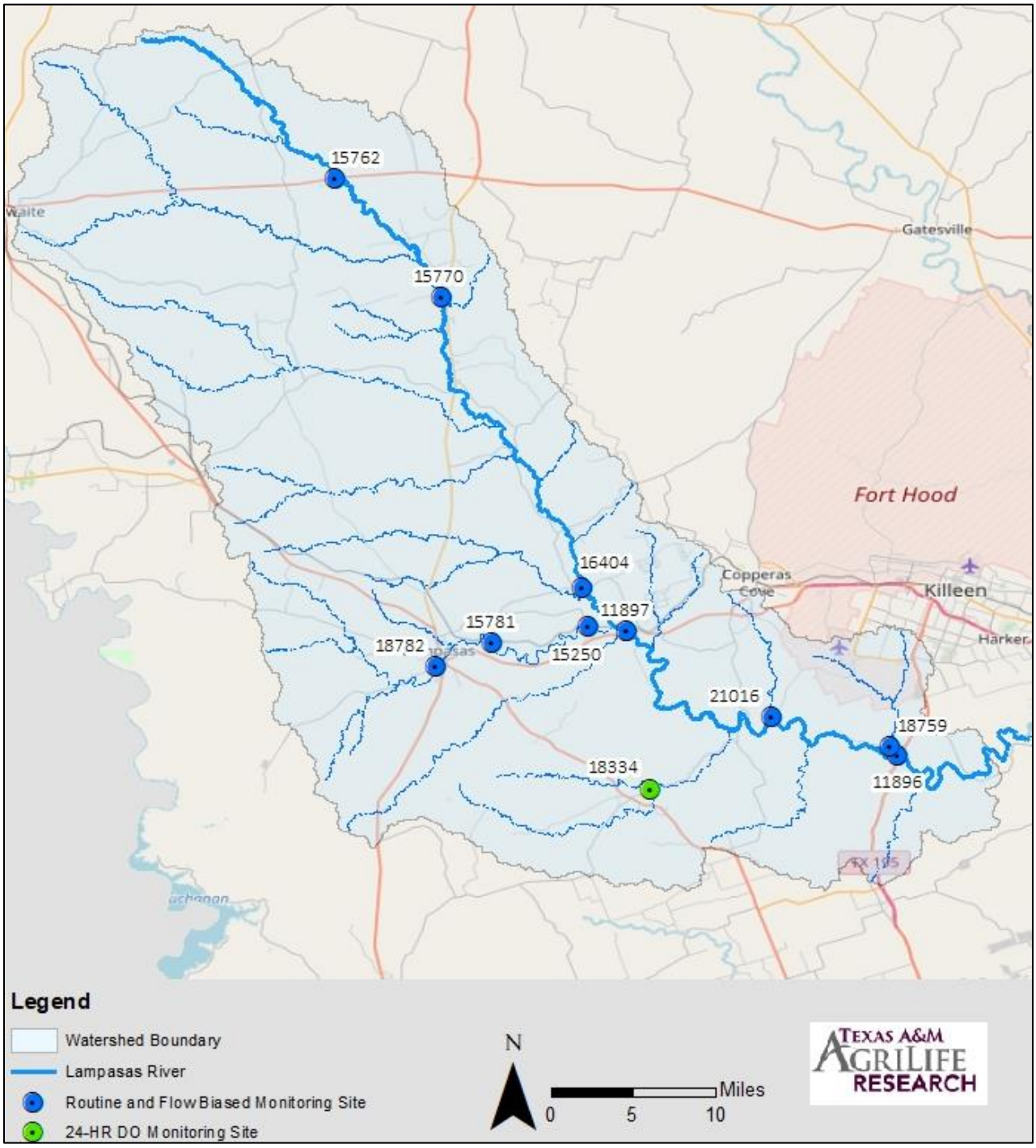


Figure 2 Ten monitoring sites were selected within the Lampasas River watershed for routine and biased flow monitoring. Station 18334 was added in 2018 to collect 24-hr dissolved oxygen samples.

TIAER also conducted biased flow monitoring at the 10 sites once per quarter/season under wet weather conditions, collecting field, conventional, flow, and bacteria parameter groups. If a routine sampling event happened to capture wet weather conditions, an additional wet weather sample was not collected that quarter.

In April of 2018, after discussion between project partners, including TSSWCB, TCEQ and BRA and the Partnership, the collection of five 24-hr DO samples at station 18334 was added to the workplan and QAPP. This revision was done in order to collect the needed additional data for the segment to be assessed with the revised site-specific standards.

Table 1 Samples were collected at 10 sites during routine and storm flow conditions over a 25-month period, in addition to 24-hr DO samples at station 18334.

TCEQ Station ID	Station Description	Monitoring Type			Total
		Routine Mainstem	Routine Tributary	Biased Flow	
15762	Lampasas River at US 84	25	NA	6	31
15770	Lampasas River at Lampasas CR 2925	25	NA	6	31
16404	Lampasas River at FM 2313	25	NA	6	31
11897	Lampasas River at US 190	25	NA	6	31
11896	Lampasas River at HWY 195	25	NA	6	31
18782	Sulphur Creek at Naruna Rd	NA	25	6	31
15781	Sulphur Creek at Lampasas CR 3010	NA	25	6	31
15250	Sulphur Creek at FM 1715	NA	25	6	31
21016	Clear Creek at Oakalla Rd	NA	25	6	31
18759	Reese Creek at FM 2670	NA	25	6	31
18334	North Fork Rocky Creek at FM 963	5	NA	NA	5

Project Highlights

Data Collection and Submittal

Data collected through this project was collected under an approved Quality Assurance Project Plan (QAPP) that was reviewed annually and updated when applicable. The objective of the quality assurance task was to develop and implement data quality objectives and quality assurance/control activities in order to ensure data of known and acceptable quality are generated through this project. The QAPP was recertified annually by project staff to ensure it

accurately reflected the data collection and handling. The QAPP was also revised in mid-2018 to include five sampling events to collect 24-hr DO samples at North Fork Rocky Creek (Station 18334).

Highlights and Evaluation of Water Quality Monitoring Data

TIAER conducted routine ambient monitoring at 10 sites monthly, collecting field, conventional, flow, and bacteria parameter groups. The objective of the routine monitoring was to provide sound water quality data to more accurately assess the current status of the Lampasas River by enhancing current routine ambient monitoring regimes. Analyzing this water quality data can show trends and the effectiveness of a WPP. TIAER and AgriLife Research coordinated with other entities, TCEQ and BRA, to avoid overlapping of resource, which allowed those agencies to focus their limited resources in other waterbodies. TIAER's laboratory also conducted the sample analysis. Field parameters were pH, temperature, conductivity, and dissolved oxygen. Conventional parameters were total suspended solids, turbidity, nitrate + nitrite nitrogen, Total Kjeldahl Nitrogen (TKN), chlorophyll-a, pheophytin, and total phosphorus (TP). Flow parameters were collected by electric, mechanical or Doppler, including severity. Bacteria parameter is E. *coli*. A full list of parameters and field codes can be found in Table 2.

Table 2 Measurement performance specifications of parameters collected.

PARAMETER	UNITS	MATRIX	METHOD	PARA-METER CODE	AWRL	LOQ	LOQ CHECK STD %Rec	PRECISION (RPD of LCS/LCS dup)	BIAS (%Rec. of LCS)	Lab
Field Parameters										
pH	pH/ units	water	SM 4500-H^+ B. and TCEQ SOP, V1	00400	NA	NA	NA	NA	NA	Field
DO	mg/L	water	SM 4500-O G. and TCEQ SOP, V1	00300	NA	NA	NA	NA	NA	Field
Specific Conductance	µS/cm	water	SM 2510 and TCEQ SOP, V1	00094	NA	NA	NA	NA	NA	Field
Temperature	°C	water	SM 2550 and TCEQ SOP, V1	00010	NA	NA	NA	NA	NA	Field
Flow	cfs	water	TCEQ SOP, V1	00061	NA	NA	NA	NA	NA	Field
Days since precipitation event	days	water	TCEQ SOP V1	72053	NA	NA	NA	NA	NA	Field

Flow measurement method	1-gage 2-electric 3-mechanical 4-weir/flume 5-doppler	water	TCEQ SOP, V1	89835	NA	NA	NA	NA	NA	Field
Flow severity	1-no flow 2-low 3-normal 4-flood 5-high 6-dry	water	TCEQ SOP, V1	01351	NA	NA	NA	NA	NA	Field
Flow Estimate	cfs	water	TCEQ SOP, V1	74069	NA	NA	NA	NA	NA	Field
Maximum pool width at time of study[1]	meters	other	TCEQ IGD	89864	NA	NA	NA	NA	NA	Field
Maximum pool depth at time of study[1]	meters	other	TCEQ IGD	89865	NA	NA	NA	NA	NA	Field
Pool length[1]	meters	other	TCEQ IGD	89869	NA	NA	NA	NA	NA	Field
% pool coverage in 500-meter reach[1]	meters	other	TCEQ IGD	89870	NA	NA	NA	NA	NA	Field
Conventional and Bacteriological Parameters										
TSS	mg/L	water	SM 2540 - D	00530	4	4	NA	NA	NA	TIAER
Chlorophyll-a, spectrophotometric method	µg/L	water	SM 10200 - H	32211	3	3	NA	NA	NA	TIAER
Pheophytin, spectrophotometric method	µg/L	water	SM 10200 - H	32218	3	3	NA	NA	NA	TIAER
E. *coli*, modified mTEC	CFU/100mL	water	EPA 1603[2]	31648	1	1	NA	0.5[3]	NA	TIAER
Total Kjeldahl Nitrogen	mg/L	water	SM 4500 – NH_3 G	00625	0.2	0.2	70-130	20	80-120	TIAER
Nitrate+Nitrite-N, total	mg/L	water	SM 4500 – NO_3 F	00630	0.05	0.05	70-130	20	80-120	TIAER
Total Phosphorus	mg/L	water	EPA 365.4	00665	0.06	0.06	70-130	20	80-120	TIAER

Beginning June 20, 2017 through July 9, 2019, monthly routine sampling events were conducted. During the first 16 months of sampling, sites 15762 and 15770, the two most upstream sites, were routinely pooled, or dry. During that same time period, Site 15762 (Lampasas River at US HWY 84), of 16 routine samples, 7 were collected in pools and another 4 events had pools insufficient to collect samples from. Site 15770 (Lampasas River at CR 2925) had 4 routine samples collected from pools and 3 events with pools insufficient to collect samples from. The 3 remaining mainstem sites had routine flow, as did the 5 tributary sites.

The following data tables compile the data collected to date at the routine sites. Table 3 compares the geometric mean of the E. *coli* data collected at each site during dry to normal conditions to the geometric mean of the data collected under high flow conditions.

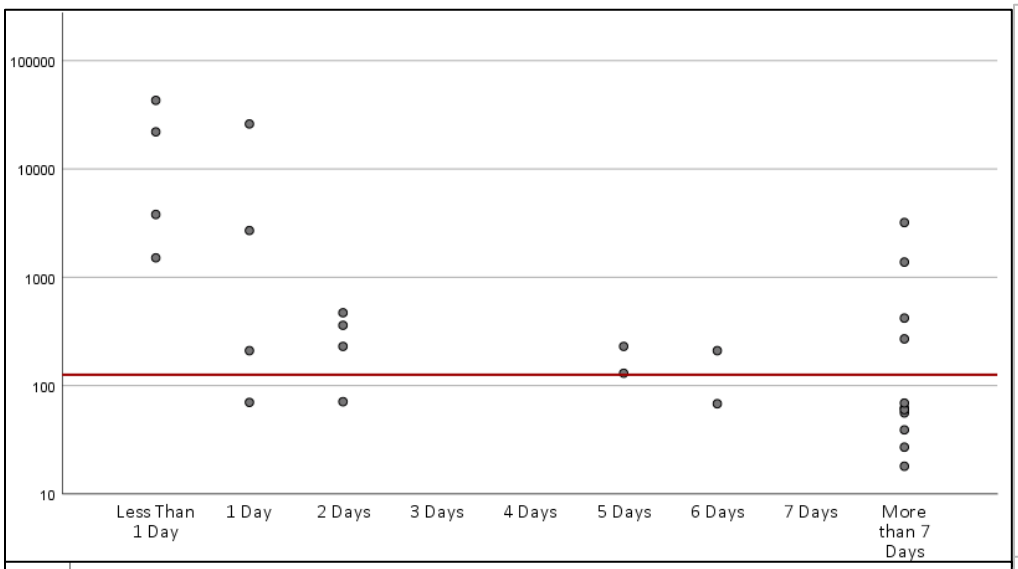
Table 3 Concentrations of E. *coli* during routine and biased flow conditions at all sites.

TCEQ Station ID	Monitoring Type													
	Routine Mainstem or Tributary Sample					Biased flow Sample					Total			
	Flow		E. *coli*			Flow		E. *coli*			Flow		E. *coli*	
	[1]N	Mean	Geo-mean	Min	Max	N	Mean	Geo-mean	Min	Max	N	Mean	Geo-mean	[2]E. *coli* % Change
Lampasas River at US 84	24	10	182	18	26000	5	3056	3814	210	43000	29	536	358	1994%
Lampasas River at CR 2925	25	36	101	4	165000	6	3445	5080	620	31000	31	696	233	4953%
Lampasas River at FM 2313	25	74	60	14	4900	6	3938	940	82	30000	31	822	102	1479%
Lampasas River at US 190	25	106	25	2	730	6	4370	1135	200	15000	31	932	53	4399%
Lampasas River at HWY 195	25	233	48	6	920	6	4997	2860	540	22000	31	1155	106	5858%
Sulphur Creek at Naruna Rd	25	14	50	10	420	6	160	410	42	6000	31	42	75	726%
Sulphur Creek at Lampasas CR 3010	25	31	57	19	340	6	310	1886	370	7500	31	85	113	3190%
Sulphur Creek at FM 1715	25	41	46	10	124	6	421	450	69	5800	31	115	71	883%
Clear Creek at Oakalla Rd	25	7	31	2	6400	6	230	4276	1290	16300	31	50	81	13654%
Reese Creek at FM 2670	25	5	94	12	4000	6	270	3977	2500	7400	31	57	195	4113%

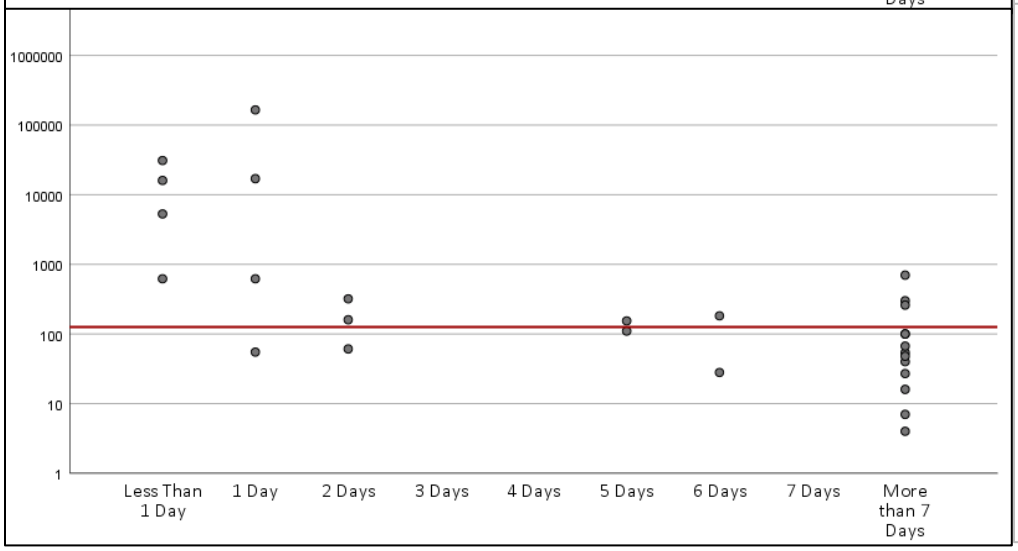
[1]Number of samples collected.

[2]Percent change in pollutant between wet and dry flows. Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration

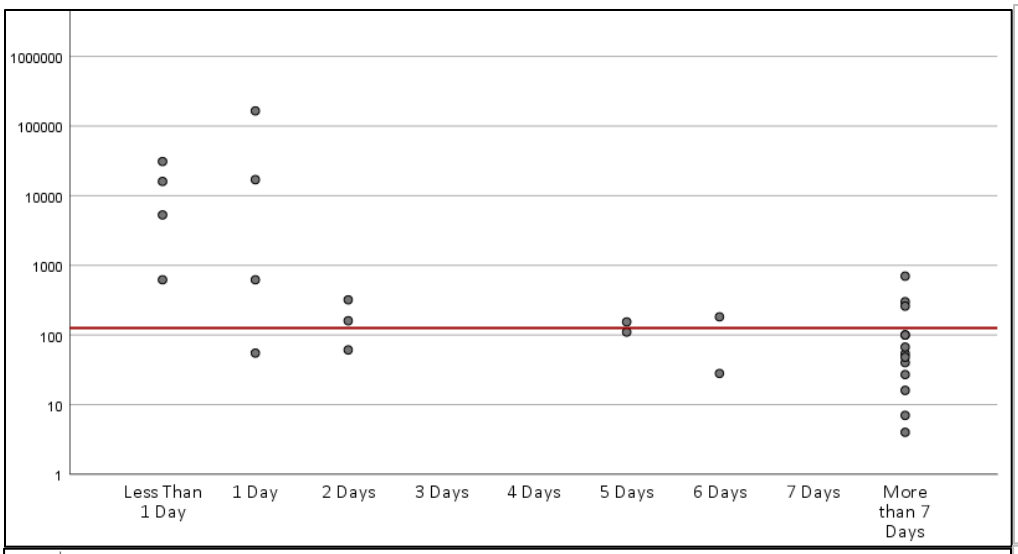
It is interesting to look at the relationship between E. *coli* and the Days Since Last Precipitation (DSLP) parameters. The following figures (Figure 3 A-E) illustrate the (log of) E. *coli* sample collected plotted on the X axis against the number of days since last precipitation on the Y axis. The red line illustrates the state standard of 126 cfu/100mL). As you move downstream, the number of samples that exceed 126 cfu/100mL during drier periods (more than 7 days since last precipitation) decreases. This may indicate that as baseflow increases, the E. *coli* concentration decreases.



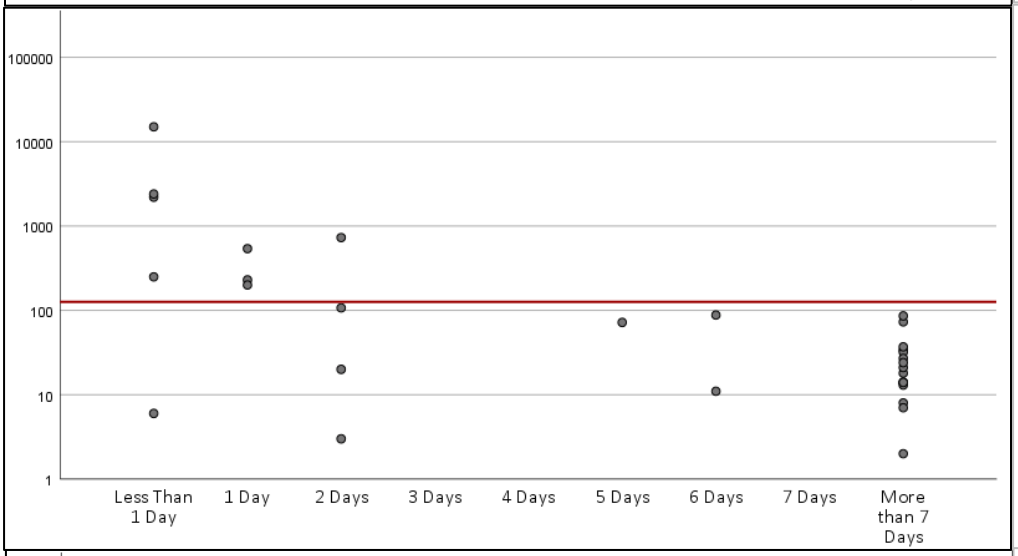
(A)
Lampasas River
at US 84
Station 15762



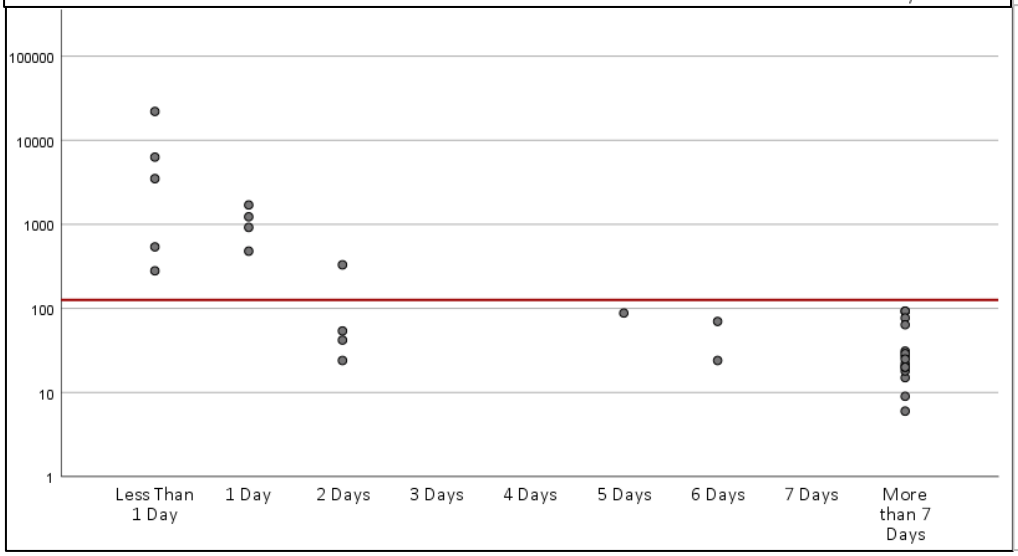
(B)
Lampasas River
at Lampasas CR 2925
Station 15770



(C)
Lampasas River
at Lampasas CR 2925
Station 15770



(D)
Lampasas River
at US 190
Station 11897



(E)
Lampasas River
at HWY 195
Station 11896

Figure 3A-E Log of E. *coli* plotted against DSLP for each sample on the mainstem of the Lampasas River.

Table 4 shows the mean of the concentrations of total phosphorus (TP) at the routine sites. Although at no time, or under any flow conditions, did the mean exceed the screening concentration of 0.69 milligrams per liter there was a significant increase in total phosphorus during wet weather conditions at all but 1 site, Clear Creek at Oakalla Rd., which showed a decrease in high flow.

Table 4 Concentrations of Total Phosphorus during routine and biased flow conditions at all sites.

TCEQ Station ID	Monitoring Type													
	Routine Mainstem or Tributary Sample					Biased flow Sample					Total			
	Flow (cfs)		TP			Flow (cfs)		TP			Flow (cfs)		TP	
	[1]N	Mean	Min	Max	Mean	N	Mean	Min	Max	Mean	N	Mean	Mean	[2]TP % Change
Lampasas River at US 84	21	10	0.030	0.231	0.088	6	3056	0.030	0.412	0.163	27	536	0.105	85%
Lampasas River at Lampasas CR 2925	20	36	0.030	0.755	0.110	6	3445	0.065	0.709	0.270	26	696	0.147	147%
Lampasas River at FM 2313	25	74	0.030	0.361	0.080	6	3938	0.030	0.858	0.194	31	822	0.102	144%
Lampasas River at US 190	25	106	0.030	0.274	0.099	6	4370	0.030	0.753	0.238	31	932	0.125	142%
Lampasas River at HWY 195	25	233	0.030	0.209	0.083	6	4997	0.030	0.565	0.208	31	1155	0.107	149%
Sulphur Creek at Naruna Rd	25	14	0.030	0.187	0.071	6	160	0.030	0.190	0.097	31	42	0.076	36%
Sulphur Creek at Lampasas CR 3010	25	31	0.030	0.821	0.199	6	310	0.119	0.357	0.196	31	85	0.198	-1%
Sulphur Creek at FM 1715	25	41	0.030	0.257	0.113	6	421	0.105	0.494	0.208	31	115	0.131	85%
Clear Creek at Oakalla Rd	25	7	0.061	0.975	0.354	6	230	0.112	0.550	0.247	31	50	0.333	-30%
Reese Creek at FM 2670	25	5	0.030	0.182	0.081	6	270	0.068	0.270	0.146	31	57	0.094	80%

[1]Number of samples collected.

[2]Percent change in pollutant between wet and dry flows. Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration

Table 5 is the mean of the concentrations of Total Kjeldahl Nitrogen at the routine sites. There was a decrease during high flow conditions at all sites.

Table 5 Concentrations of Total Kjeldahl Nitrogen (TKN) under low to normal and high flow conditions at all monitoring sites.

TCEQ Station ID	Monitoring Type													
	Routine Mainstem Sample					Biased flow Sample					Total			
	Flow (cfs)		TKN			Flow (cfs)		TKN			Flow (cfs)		TKN	
	[1]N	Mean	Min	Max	Mean	N	Mean	Min	Max	Mean	N	Mean	Mean	[2]TKN % Change
Lampasas River at US 84	21	10	0.1	2.257	0.8244	6	3056	0.383	1.679	0.997	27	536	0.8627	-17%
Lampasas River at Lampasas CR 2925	20	36	0.1	2.415	0.6431	6	3445	0.533	2.709	1.2796	26	696	0.79	-50%
Lampasas River at FM 2313	25	74	0.1	0.784	0.3966	6	3938	0.363	3.173	0.9855	31	822	0.5106	-60%
Lampasas River at US 190	25	106	0.1	1.219	0.476	6	4370	0.331	2.548	1.0413	31	932	0.5854	-54%
Lampasas River at HWY 195	25	233	0.1	1.746	0.4358	6	4997	0.308	2.304	1.1042	31	1155	0.5651	-61%
Sulphur Creek at Naruna Rd	25	14	0.1	1.01	0.3971	6	160	0.1	0.857	0.4092	31	42	0.3995	-3%
Sulphur Creek at Lampasas CR 3010	25	31	0.1	1.502	0.5032	6	310	0.374	1.3	0.7109	31	85	0.5434	-29%
Sulphur Creek at FM 1715	25	41	0.1	6.555	0.7133	6	421	0.377	1.634	0.7607	31	115	0.7225	-6%
Clear Creek at Oakalla Rd	24	7	0.1	1.867	0.6312	6	230	0.24	1.13	0.718	30	50	0.6486	-12%
Reese Creek at FM 2670	25	5	0.1	1.993	0.3905	6	270	0.378	1.01	0.7058	31	57	0.4515	-45%

[1]Number of samples collected.

[2]Percent change in pollutant between wet and dry flows. Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration

Analysis of Lampasas River Mainstem Data for Trends

Each of the monitoring stations were analyzed for statistically significant correlations between concentrations for E. *coli, total* phosphorus, and total Kjeldahl nitrogen versus stream flow. A simple linear regression was calculated to predict each of the three parameters above based on flow. If the p value was less than or equal to a 0.05 significance level, then the correlation between each of the dependent variables and stream flow was considered to be significant. The solid red lines on the accompanying charts represent the primary contact recreation limit for E. *coli*, if applicable.

15762: Lampasas River at US 84

The Lampasas River at US Hwy 84 monitoring site, (station 15762) is located in the northern portion of the watershed in western Hamilton County and is the most upstream sampling location. The upstream drainage area is primarily rangeland. From June 2017 thru September 2018, many samples were either collected from pools or not collected at all, due to insufficient pool size per TCEQ SWQM standards. Out of 16 routine samples collected during that time period, 7 were collected in pools and 4 events collect samples due to insufficient pool size. In addition, 1 of the 2 biased flow samples was collected from a pool as well. Only one statistically significant correlation with flow was found at this location. While E. *coli* and TKN were not significantly correlated with flow, total phosphorus; $F(1,23)= 38.749$, $p<.000$ (Figure 4).

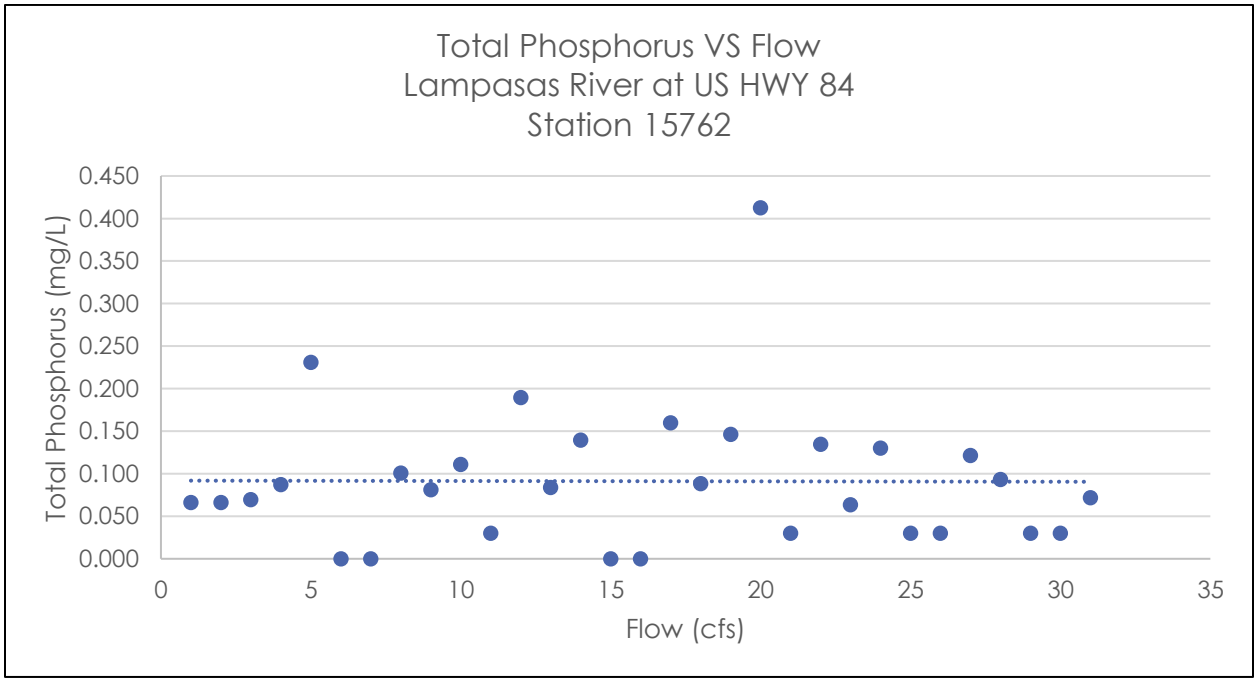


Figure 4 Total Phosphorus (mg/L) verses flow (cfs) at station 15762, Lampasas River at US HWY 84.

15770: Lampasas River at CR 2925

The Lampasas River at Lampasas County Rd 2925 monitoring station, (station 15770) is located in northern Lampasas County approximately 2.5 miles downstream of the Bennett Creek confluence. The upstream drainage area is primarily rangeland. Like the station upstream, from June 2017 thru September 2018, several samples were either collected from pools or not collected at all, due to insufficient pool size per TCEQ SWQM standards. Out of 16 routine

samples collected during that time period, 4 were collected in pools and 3 events collect samples due to insufficient pool size. Only one statistically significant correlation with flow was found at this location. While E. *coli* was not significantly correlated with flow, TKN F(1,24)= 15.304, p<.001 (Figure 5) and TP F(1,24)= 14.671, p<.001 (Figure 6) were significantly correlated.

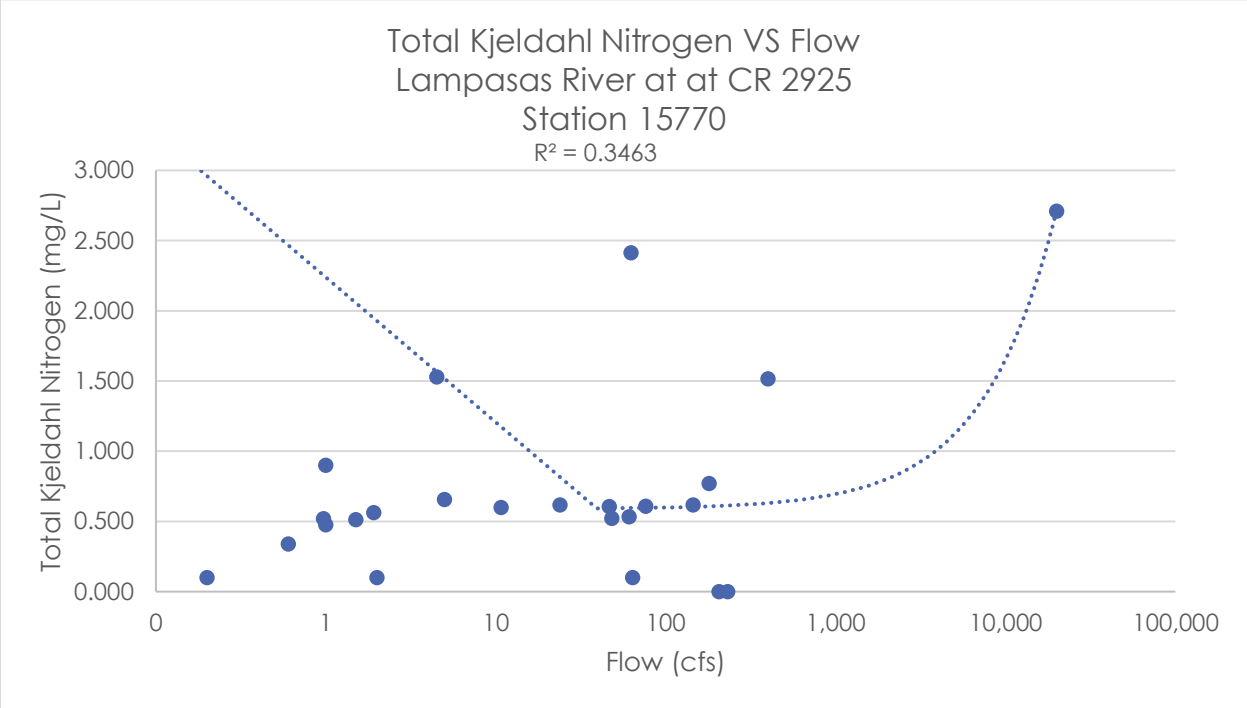


Figure 5 Total Kjeldahl Nitrogen (mg/L) verses log of flow (cfs) at station 15770, Lampasas River at CR 2925.

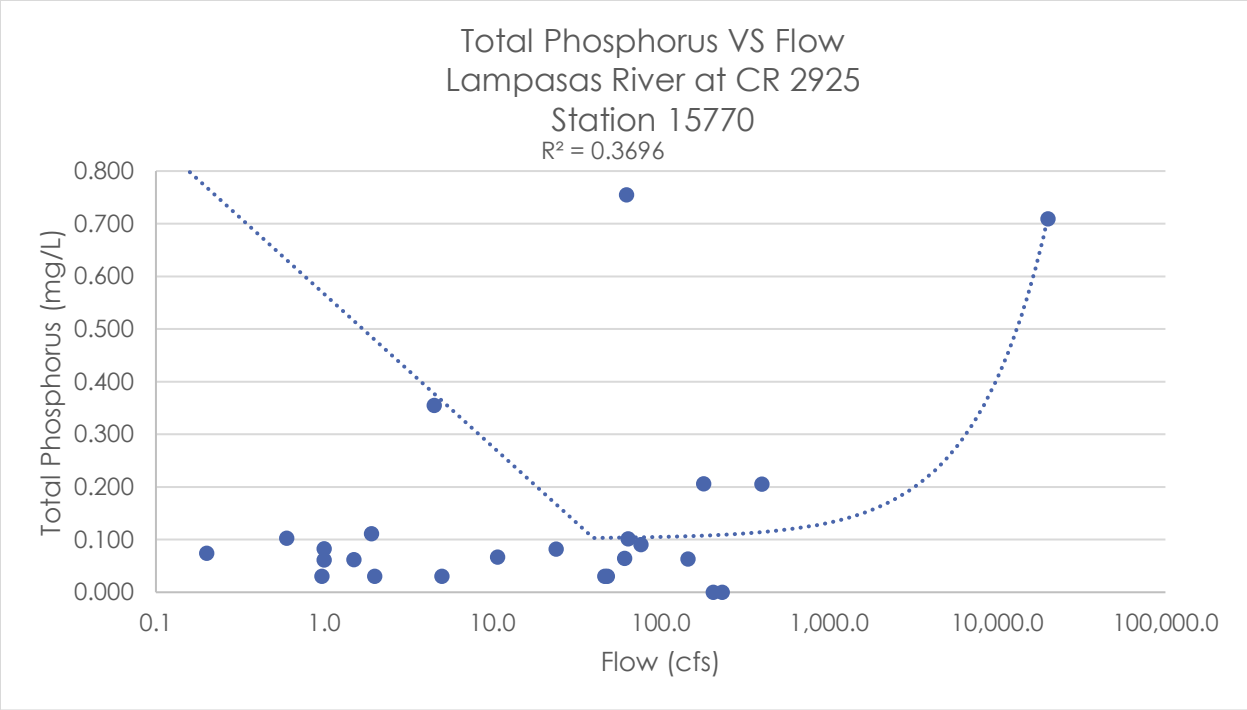


Figure 6 Total Phosphorus (mg/L) verses log of flow (cfs) at station 15770, Lampasas River at CR 2925.

16404: Lampasas River at FM 2313

The Lampasas River at FM 2313 monitoring station (station 16404), is located in southern Lampasas County approximately 2.8 miles upstream of the Sulphur Creek confluence. The upstream drainage area is primarily rangeland. Statistically significant correlations with flow were found with 3 parameters at this location. E. *coli* was significantly correlated with flow, $F(1,29)= 998.11$, $p<.000$ (Figure 7), along with both total Kjeldahl nitrogen; $F(1,29)= 151.496$, $p<.000$ (Figure 8) and total phosphorus; $F(1,29)= 128.404$, $p<.000$ (Figure 9) increase as flow increases.

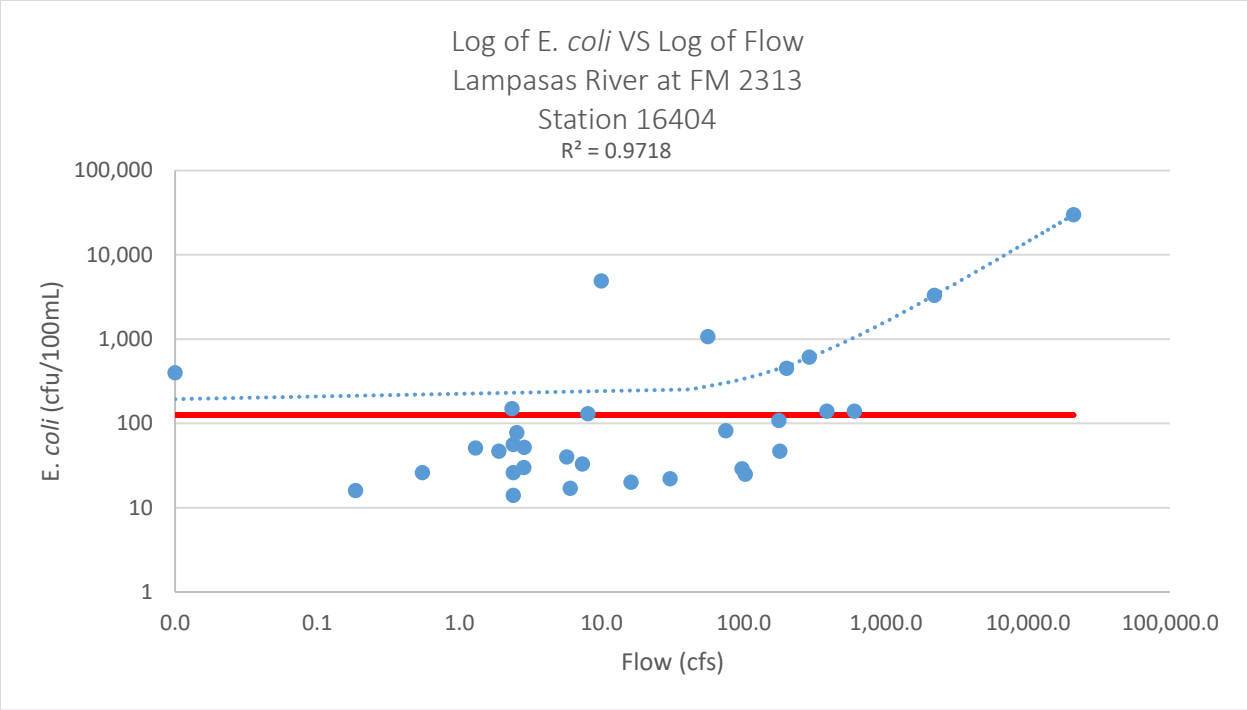


Figure 7 Log of E. *coli* (cfu/100mL) versus log of flow (cfs) at station 16404, Lampasas River at FM 2313.

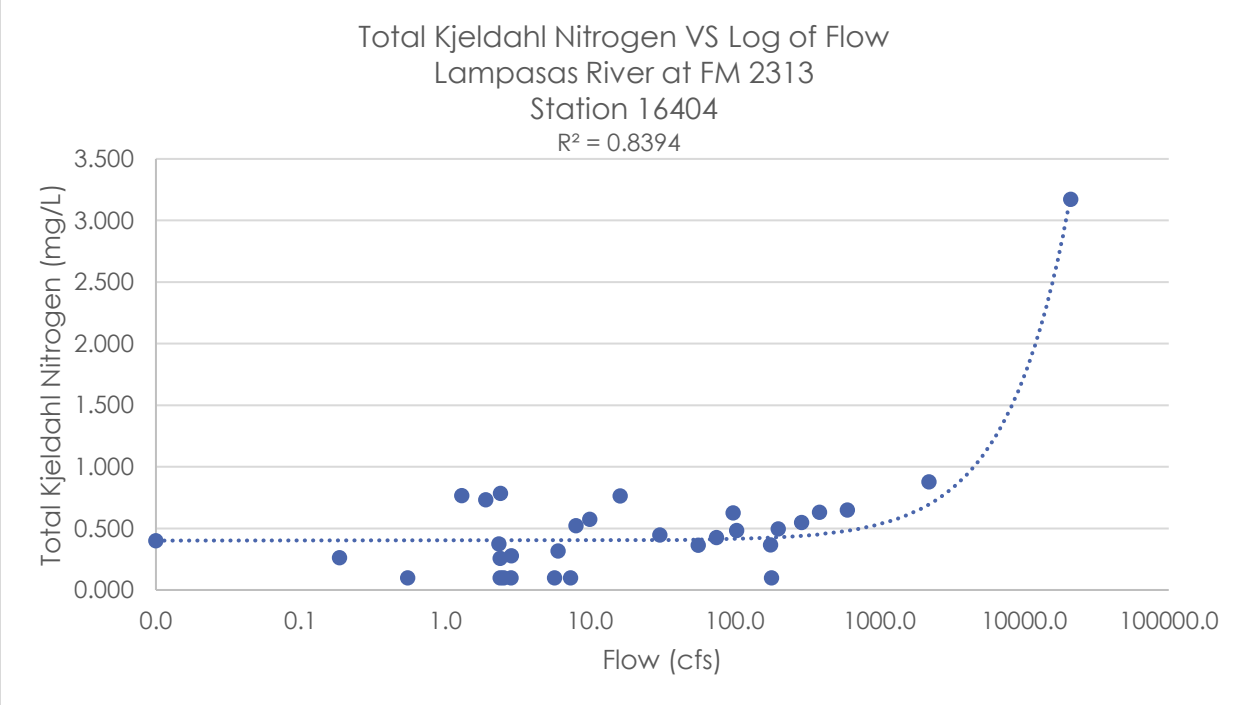


Figure 8 Total Kjeldahl Nitrogen (mg/L) versus log of flow (cfs) at station 16404, Lampasas River at FM 2313.

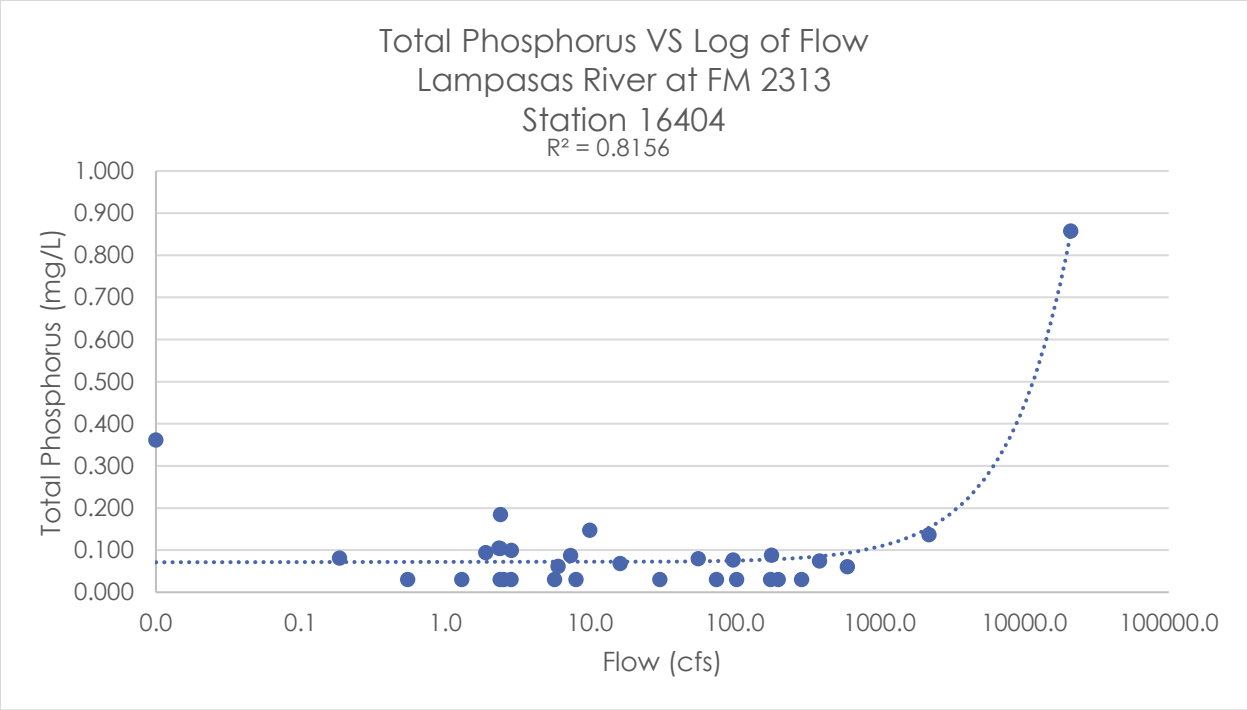


Figure 9 Total Phosphorus (mg/L) verses log of flow (cfs) at station 16404, Lampasas River at FM 2313.

11897: Lampasas River at US 190

The Lampasas River at US HWY 190 monitoring station (station 11897) is located in southern Lampasas County approximately 0.8 miles downstream of its confluence with Sulphur Creek. The upstream drainage area is primarily rangeland although its summer flows are heavily influenced by Sulphur Creek, which includes the city of Lampasas. Statistically significant correlations with flow were found with 3 parameters at this location. E. *coli* was significantly correlated with flow, $F(1,29)= 1175.898$, $p<.000$ (Figure 10), along with both total Kjeldahl nitrogen; $F(1,29)= 40.62$, $p<.000$ (Figure 11) and total phosphorus; $F(1,29)= 70.775$, $p<.000$ (Figure 12). All three parameters were positively correlated with flows.

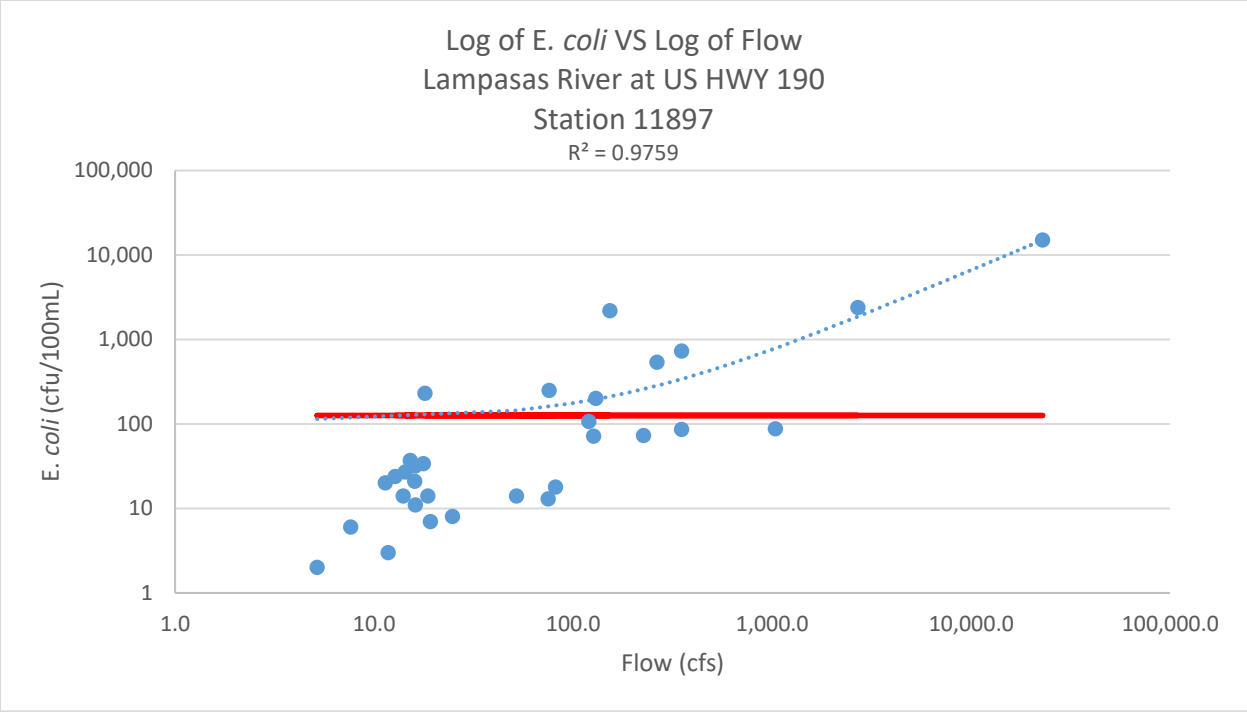


Figure 10 Log of E. *coli* (cfu/100mL) versus flow (cfs) at station 11897, Lampasas River at US HWY 190.

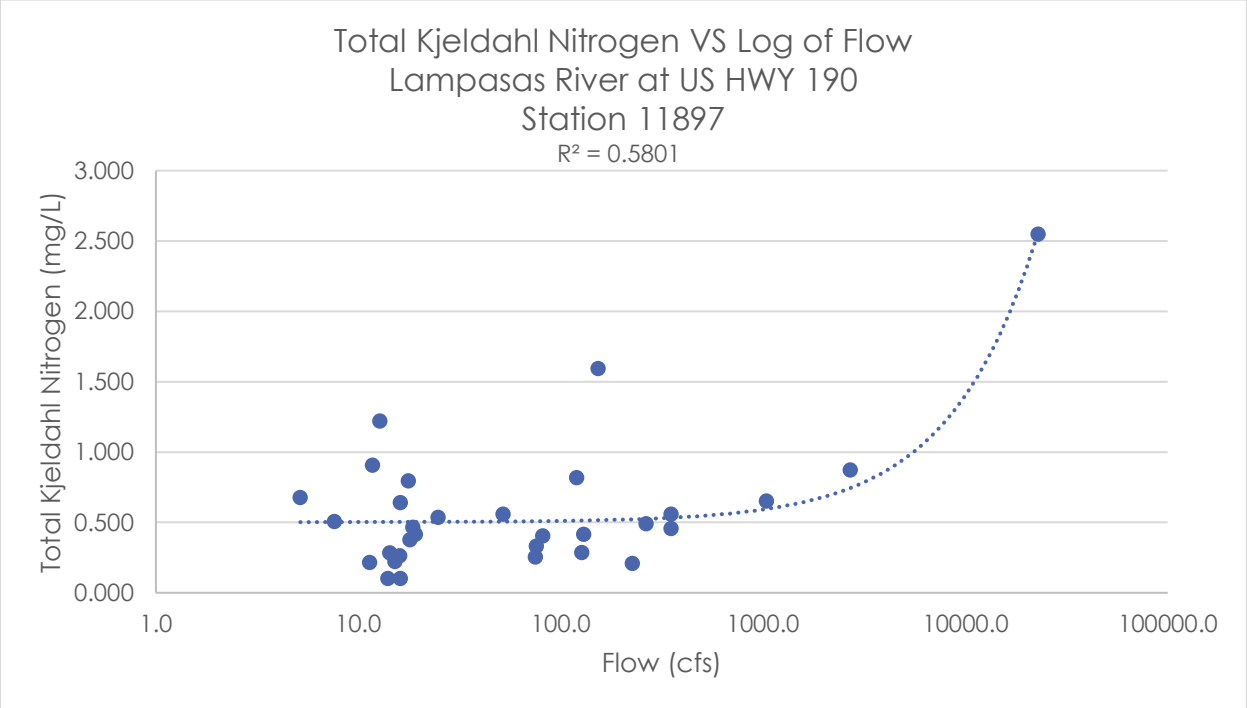


Figure 11 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at station 11897, Lampasas River at US HWY 190.

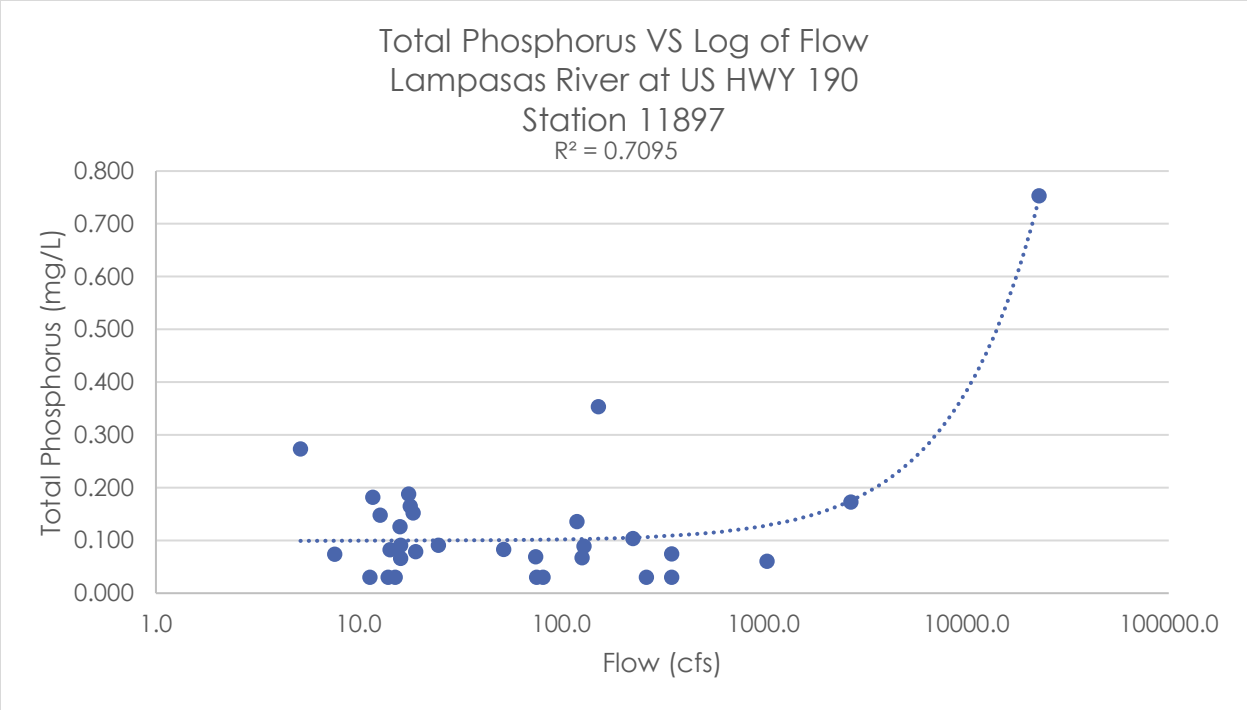


Figure 12 Total Phosphorus (mg/L) verses flow (cfs) at station 11897, Lampasas River at US HWY 190.

11896: Lampasas River at HWY 195

The Lampasas River at State HWY monitoring station (station 11896) is located in eastern Bell County, approximately 7 miles upstream of its confluence with Stillhouse Hollow Lake. The upstream drainage area is primarily rangeland. This is the most downstream station for the Lampasas River. All monitored tributaries are also upstream from this location. Several statistically significant correlations with flow were found at this location. E. *coli* was significantly correlated with flow, $F(1,29)= 318.236$, $p<.000$ (Figure 13), along with both total Kjeldahl nitrogen; $F(1,29)= 16.577$, $p<.000$ (Figure 14) and total phosphorus; $F(1,29)= 55.317$, $p<.000$ Figure 15). All three parameters were positively correlated with flows.

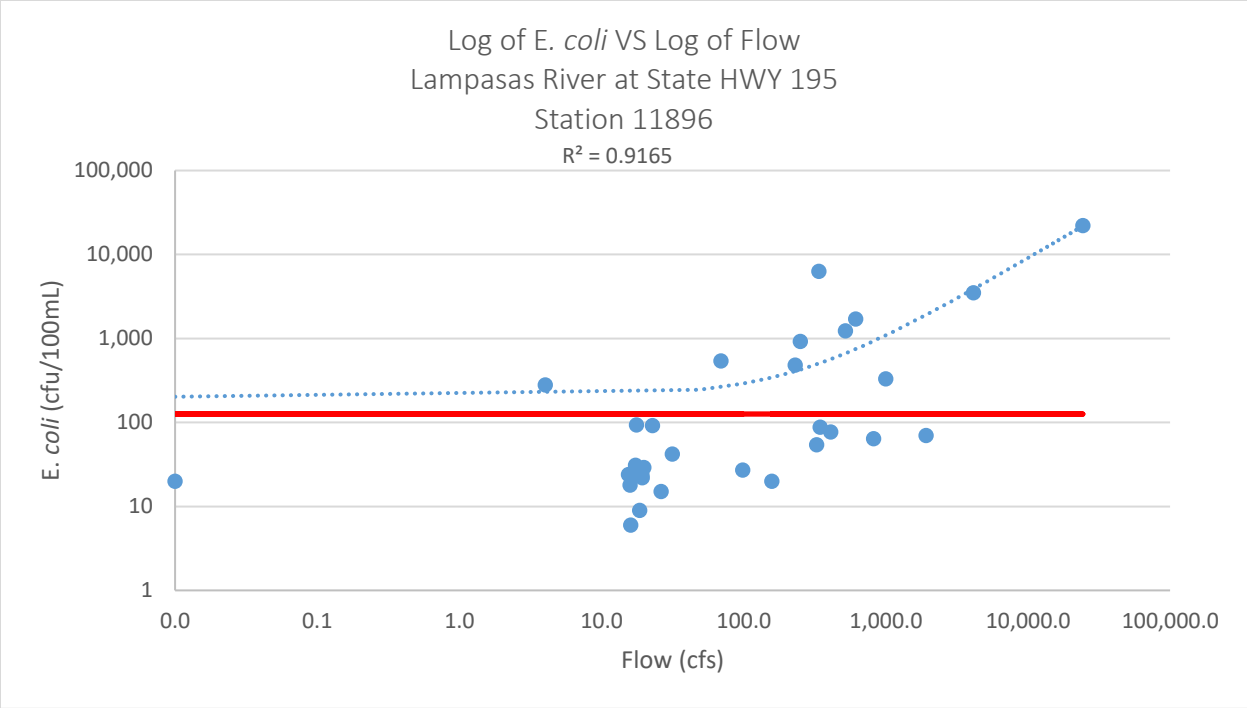


Figure 13 Log of E. *coli* (cfu/100mL) versus flow (cfs) at station 11897, Lampasas River at State HWY 195.

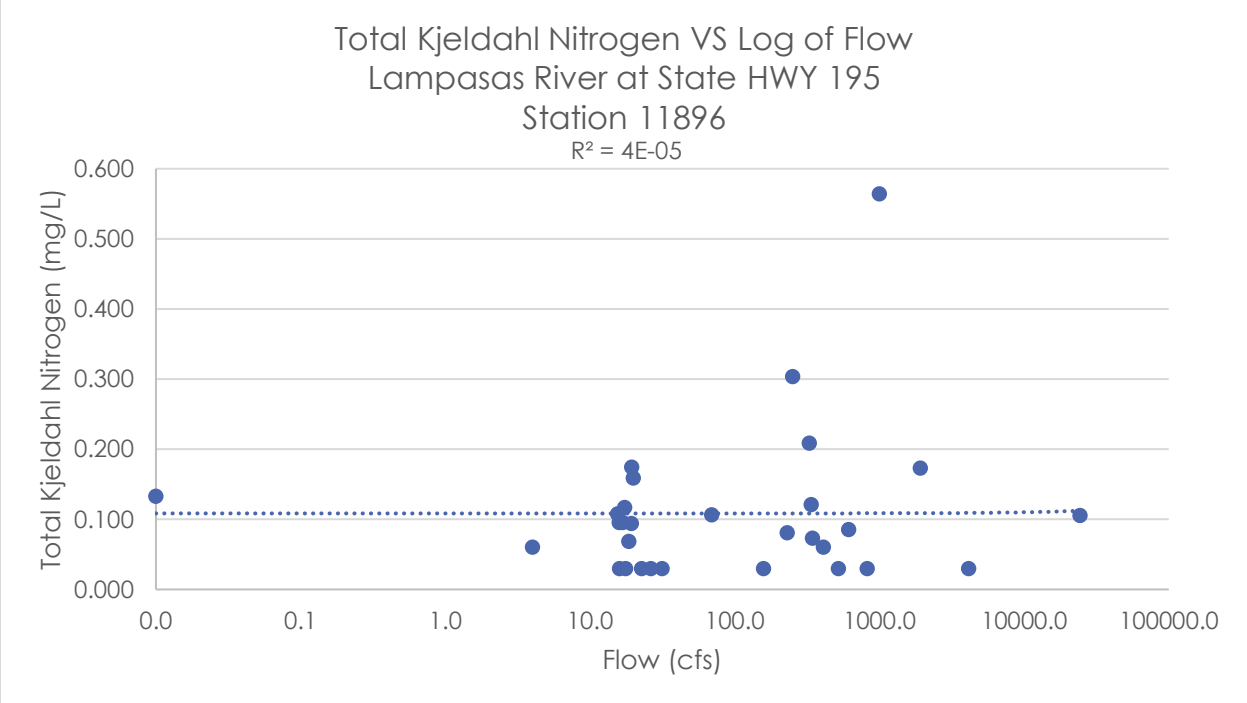


Figure 14 Total Kjeldahl Nitrogen (mg/L) verses log of flow (cfs) at station 11896, Lampasas River at State HWY 195.

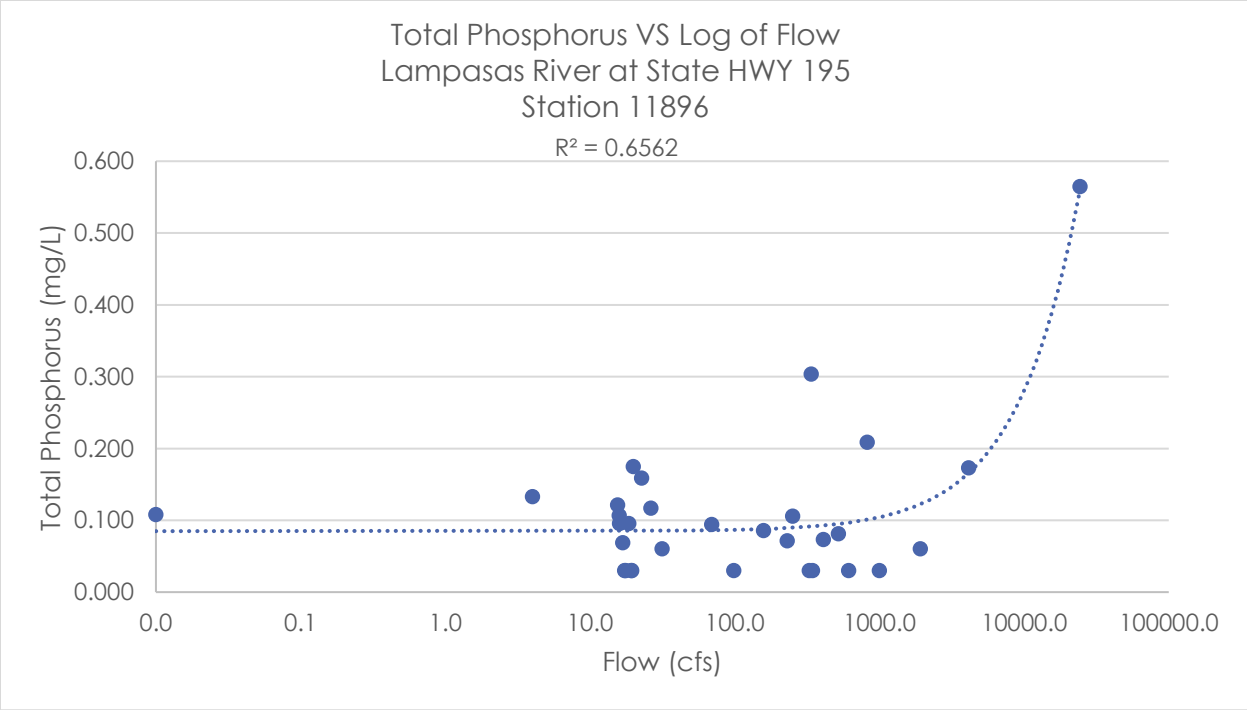


Figure 15 Total Phosphorus (mg/L) verses of flow (cfs) at station 11896, Lampasas River at State HWY 195.

Analysis of Major Tributary Data for Trends

18782: Sulphur Creek at Naruna Road

The Sulphur Creek at Naruna Rd monitoring station (station 18782) is located in southern Lampasas County. This station is upstream from the city of Lampasas, although the upstream drainage area is primarily rangeland. Several statistically significant correlations with flow were found at this location. E. *coli* was significantly correlated with flow, $F(1,29)= 300.017$, $p<.000$ (Figure 16), along with both total Kjeldahl nitrogen; $F(1,29)= 4.90$, $p<.034$ (Figure 17) and total phosphorus; $F(1,29)= 6.617$, $p<.015$ (Figure 18). All three parameters were positively correlated with flows.

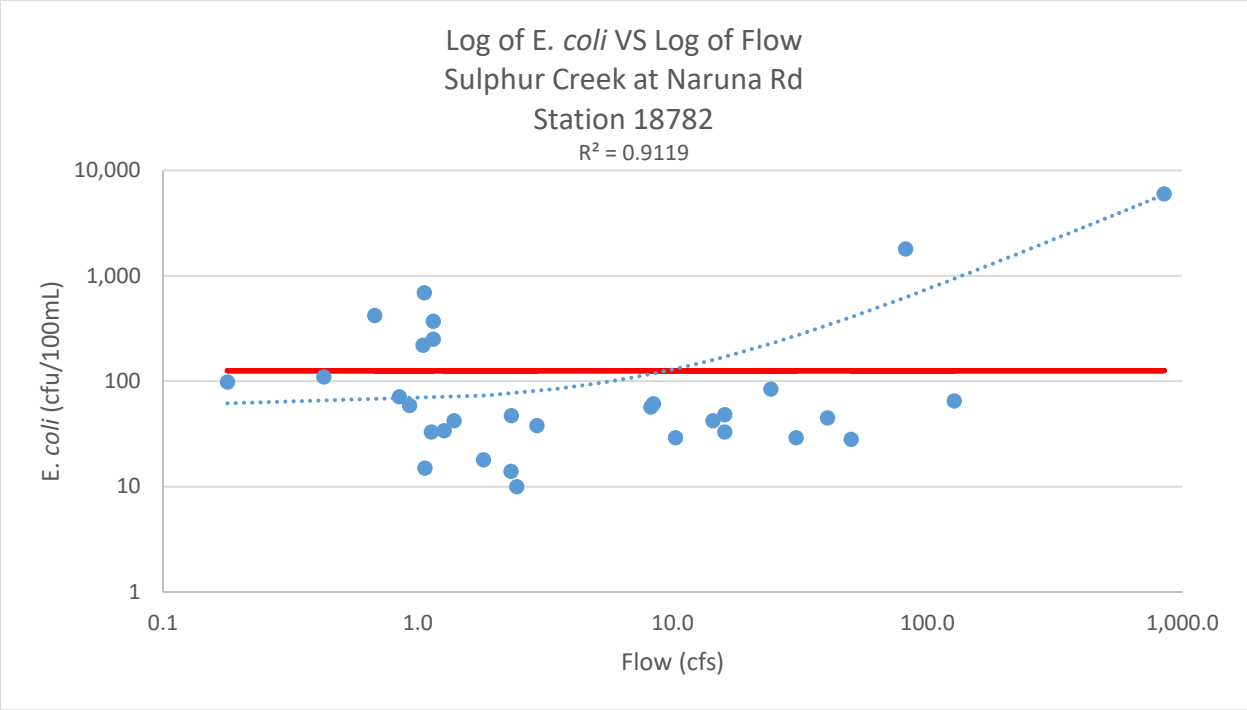


Figure 16 Log of E. *coli* (cfu/100mL) versus flow (cfs) at station 18782, Sulphur Creek at Naruna Road.

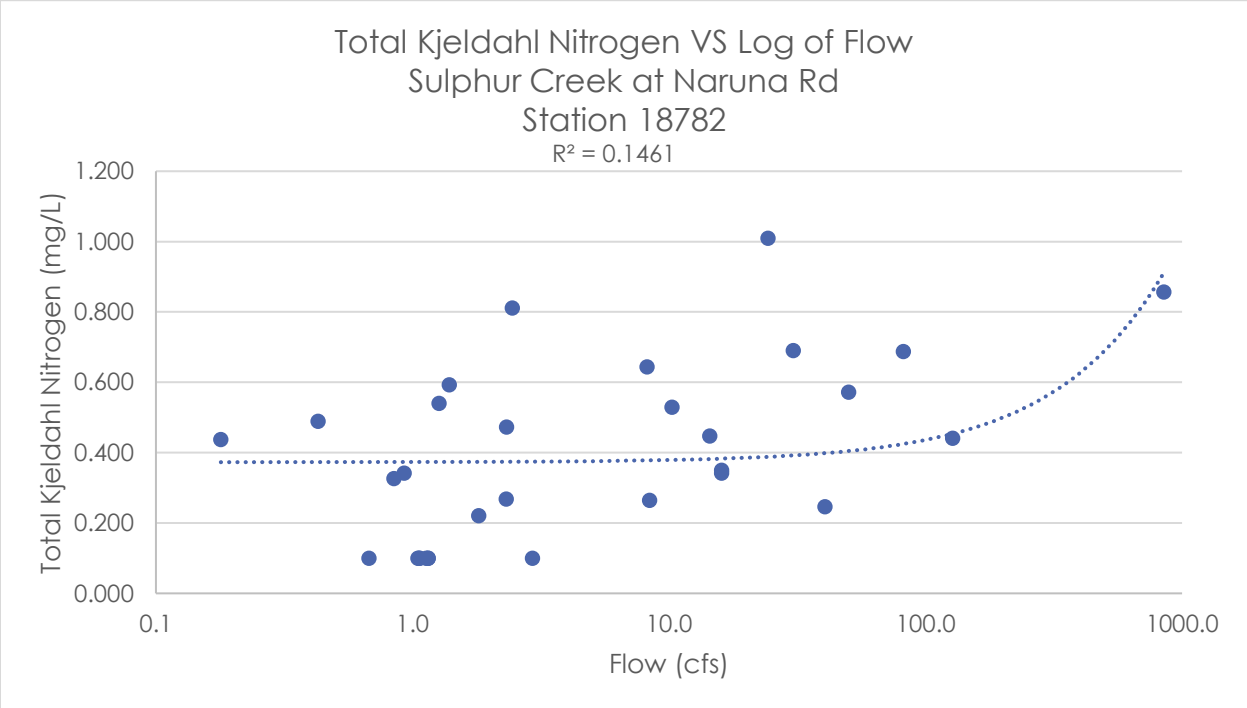


Figure 17 Total Kjeldahl Nitrogen (mg/L) verses log of flow (cfs) at station 18782, Sulphur Creek at Naruna Road.

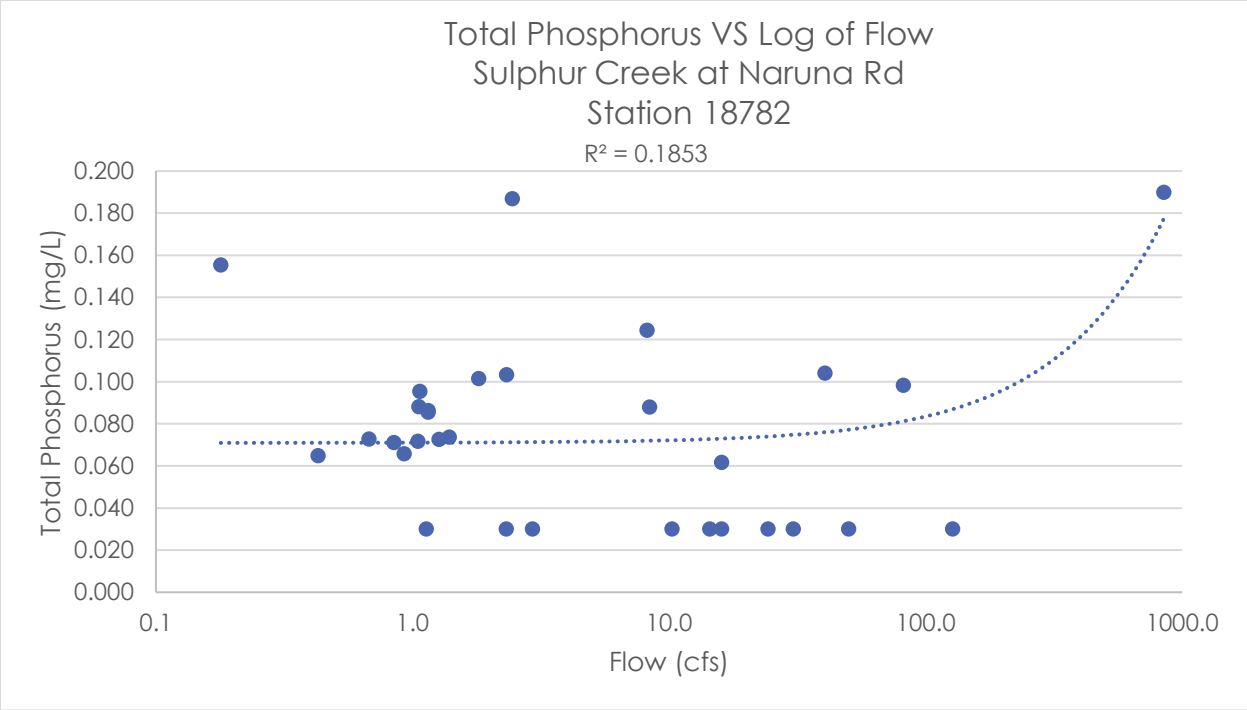


Figure 18 Total Phosphorus (mg/L) verses log of flow (cfs) at station 18782, Sulphur Creek at Naruna Road.

15781: Sulphur Creek at CR 3010

The Sulphur Creek at Lampasas County Rd 3010 monitoring station (station 15781) is located in southern Lampasas County, several miles east of the city of Lampasas. Several statistically significant correlations with flow were found at this location. E. *coli* was significantly correlated with flow, $F(1,29)= 31.427$, $p<.000$ (Figure 19), along with total Kjeldahl nitrogen; $F(1,29)= 5.980$, $p<.021$ (Figure 20). Both parameters were positively correlated with flows.

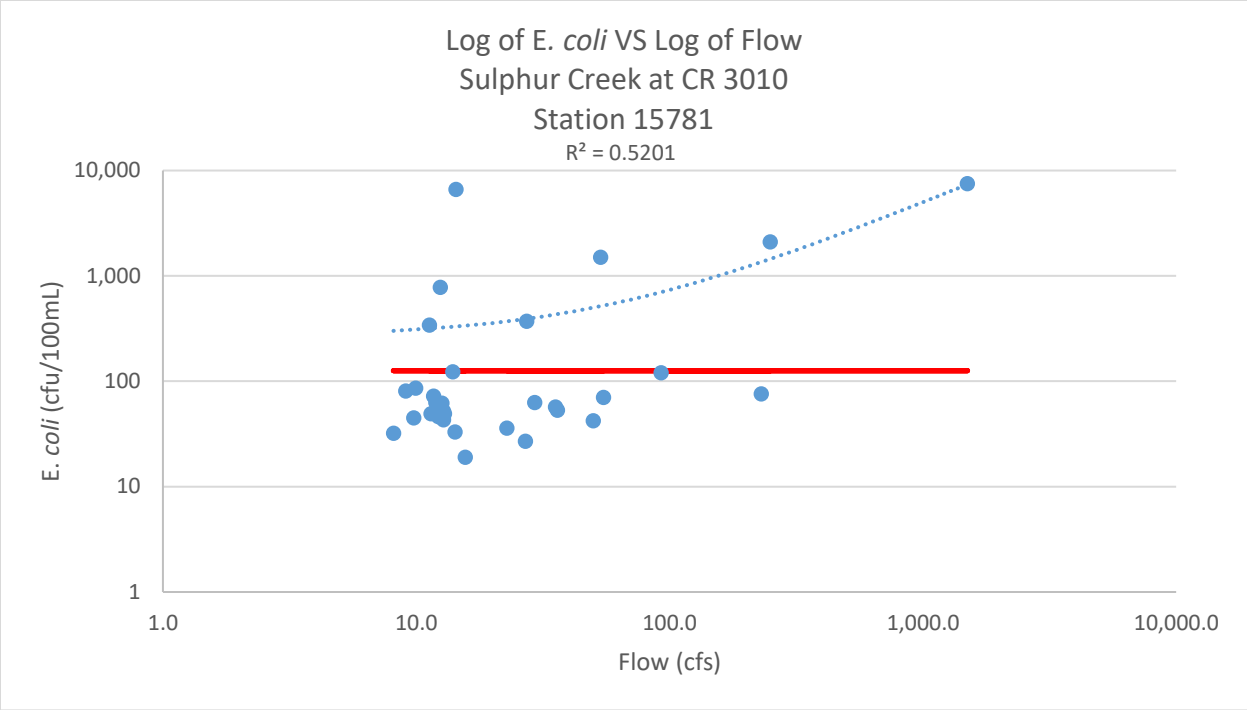


Figure 19 Log of E. *coli* (cfu/100mL) versus flow (cfs) at station 15781, Sulphur Creek at County Road 3010.

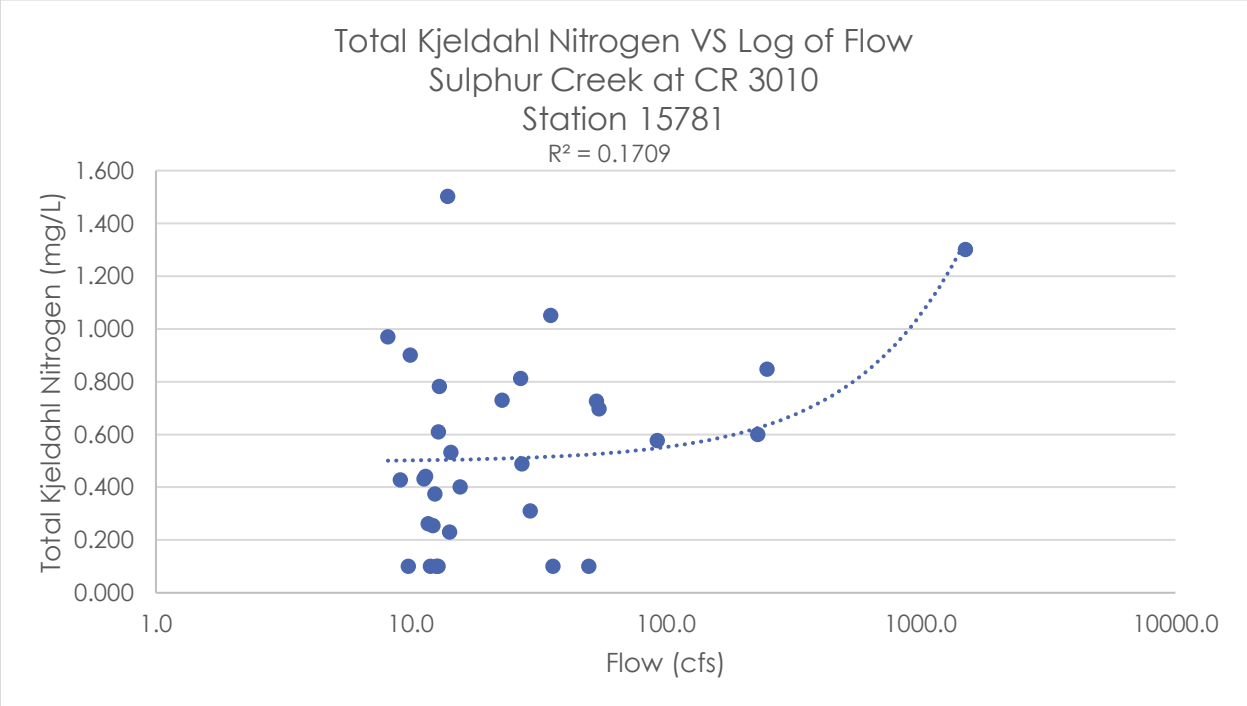


Figure 20 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at station 15781, Sulphur Creek at County Road 3010.

15250: Sulphur Creek at FM 1715

The Sulphur Creek at FM 1715 monitoring station (station 15250) is located in southern Lampasas County, approximately 1.5 miles upstream from Sulphur Creek's confluence with the Lampasas River. Several statistically significant correlations with flow were found at this location. E. *coli*; F(1,29)= 164.694, p<.000 (Figure 21) and total phosphorus; F(1,29)= 30.3320, p<.000 (**Error! Reference source not found.**) were both positively correlated with flow and increased as flow increases.

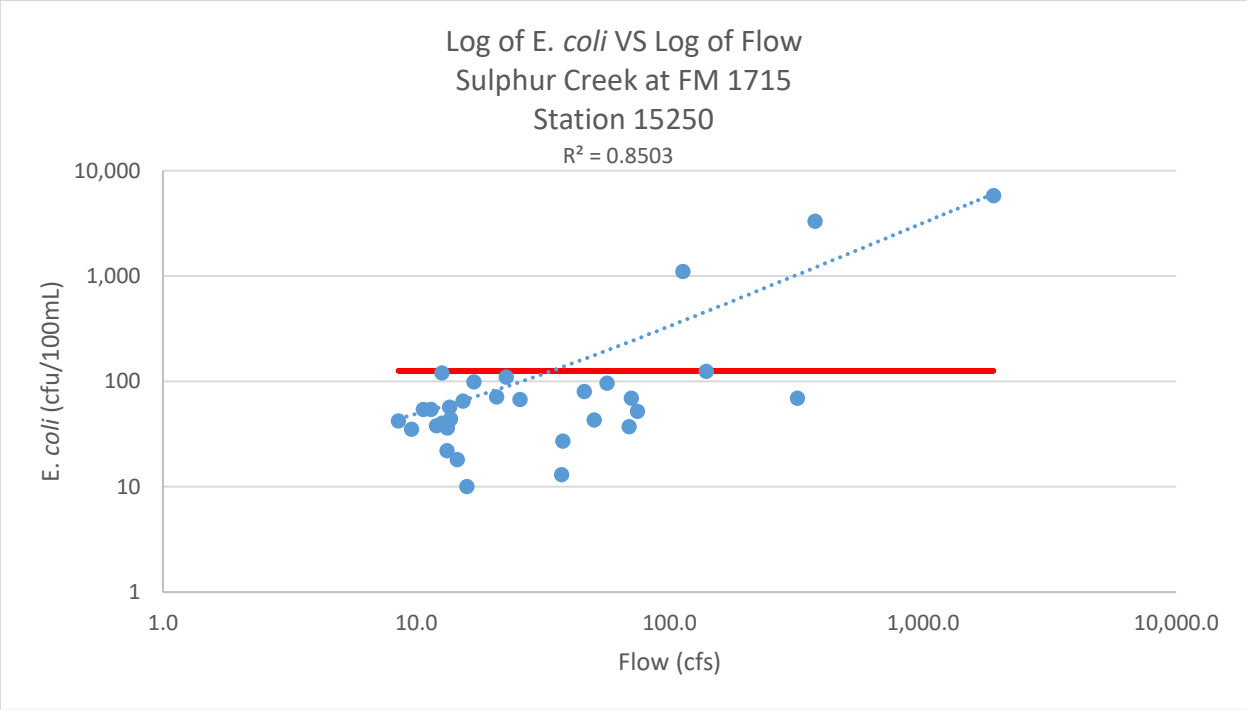


Figure 21 Log of E. *coli* (cfu/100mL) versus flow (cfs) at station 15250, Sulphur Creek at FM 1715.

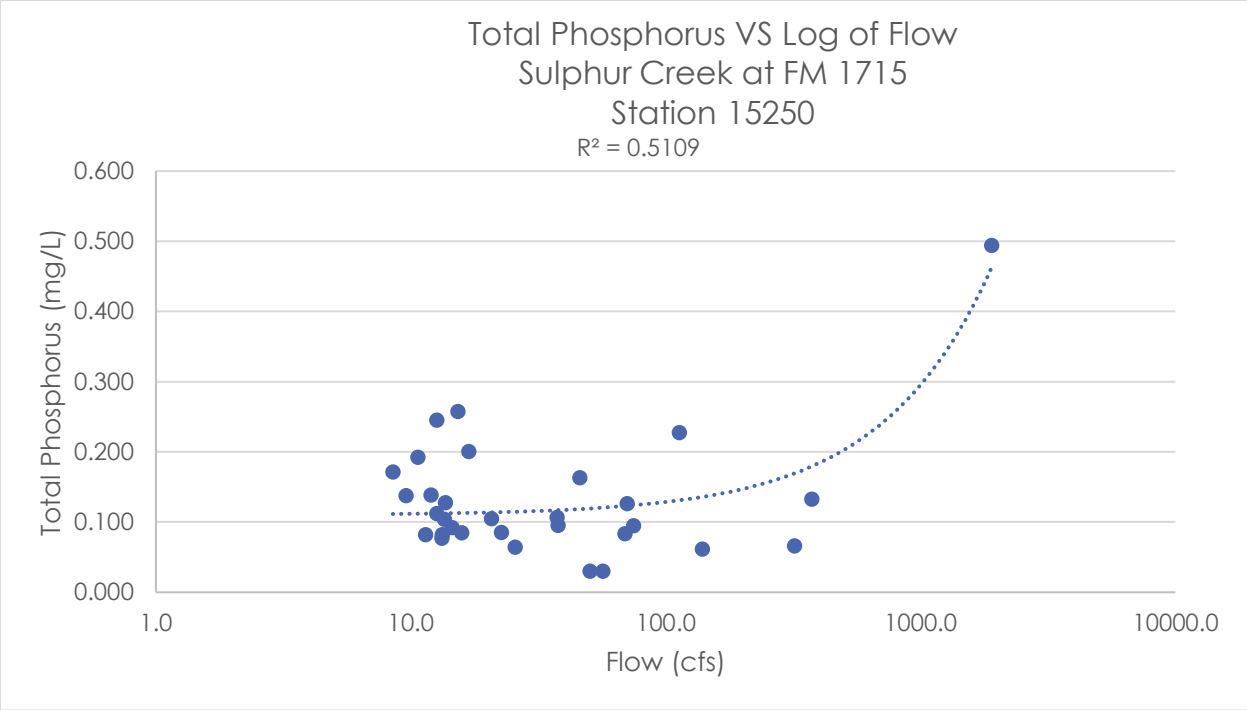


Figure 22 Total Phosphorus (mg/L) verses log of flow (cfs) at station 15250, Sulphur Creek at FM 1715.

21016: Clear Creek at Oakalla Road

The Clear Creek at Oakalla Road monitoring station (station 21016) is located in eastern Burnet County, approximately 0.5 miles upstream from its confluence with the Lampasas River. Clear Creek originates in southwestern area of the city of Copperas Cove and is partially residential/urban and partially rangeland land use. Statistically significant correlations with flow was only found with 1 parameter at this location. E. *coli* was significantly correlated with flow, $F(1,29)= 4.332$, $p<.046$ (**Error! Reference source not found.**). E. *coli* was positively correlated with flows.

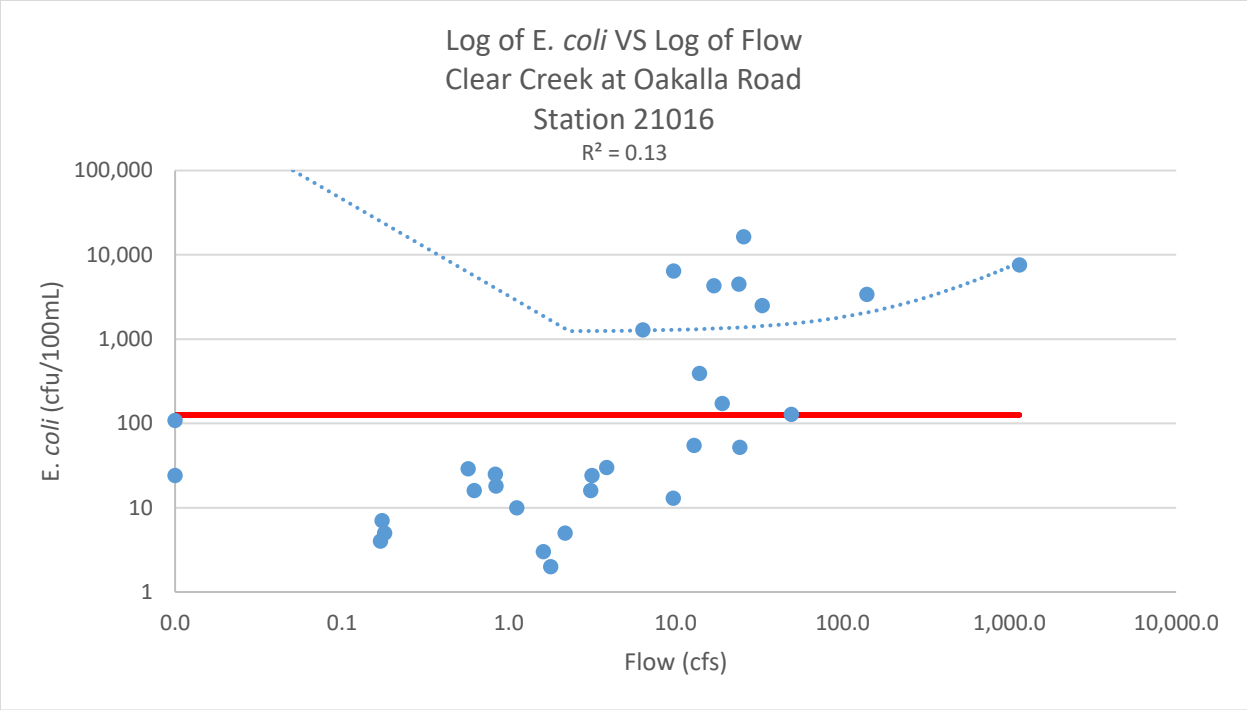


Figure 23 Log of E. *coli* (cfu/100mL) versus flow (cfs) at station 21016, Clear Creek at Oakalla Road.

18759: Reese Creek near FM 2670

The Reese Creek near FM 2670 monitoring station (station 18759) is located in western Bell County, approximately 0.4 mile upstream from its confluence with the Lampasas River. Reese Creek originates in southwestern area of the city of Killeen and is partially residential/urban and partially rangeland land use. Statistically significant correlations with flow were found with 2 parameters at this location. E. *coli* was significantly correlated with flow, $F(1,29)= 5.198$, $p<.030$ (**Error! Reference source not found.**), along with total phosphorus; $F(1,29)= 8.642$, $p<.006$ (**Error! Reference source not found.**). Both parameters were positively correlated with flow and increased as flow increased.

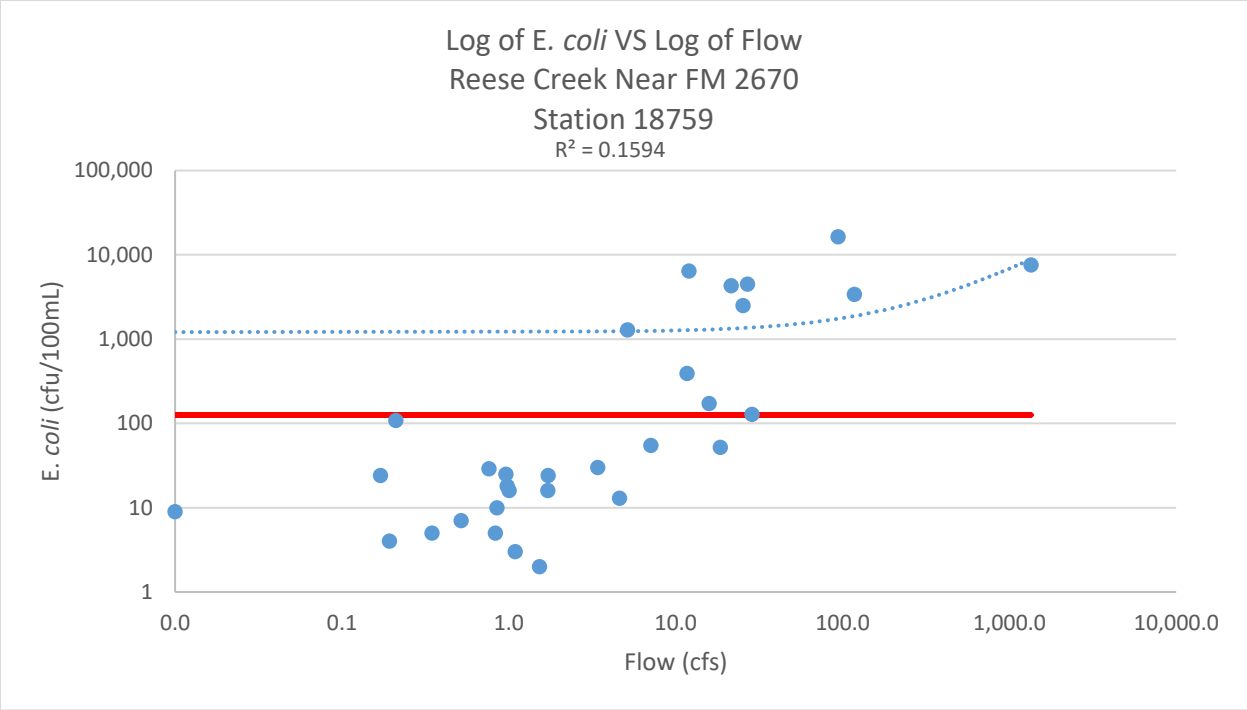


Figure 24 Log of E. *coli* (cfu/100mL) versus flow (cfs) at station 18759, Reese Creek near FM 2670

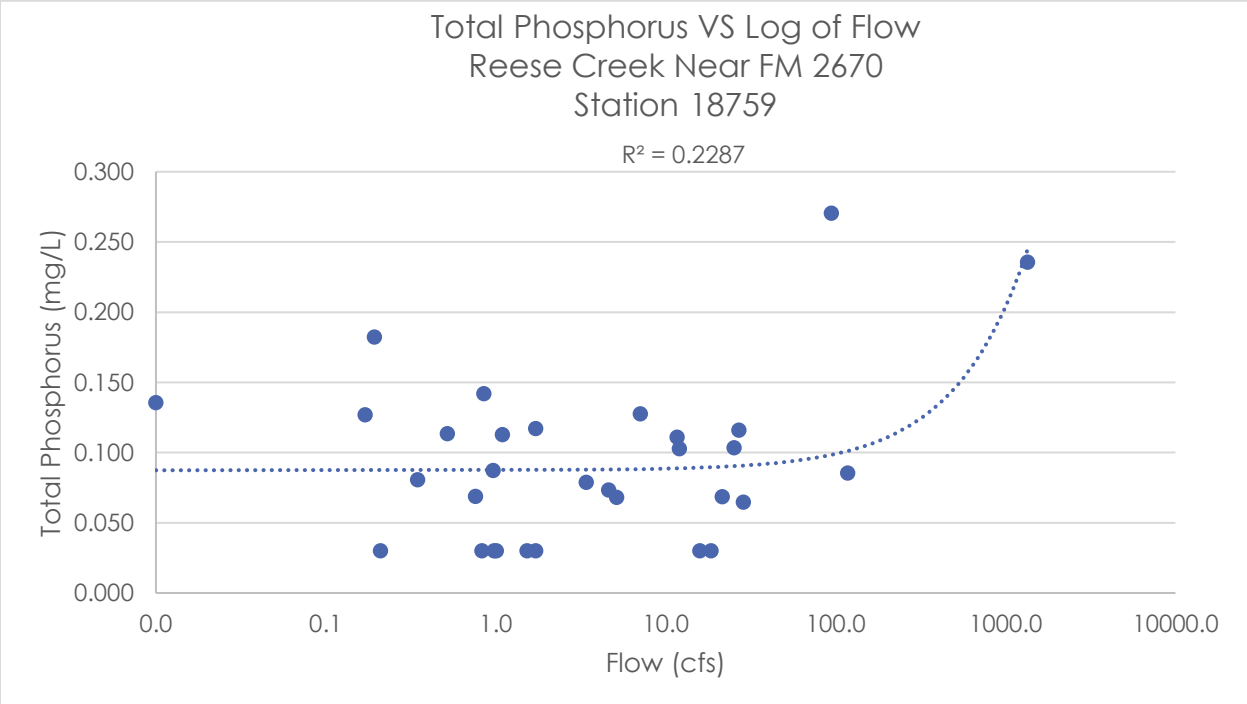


Figure 25 Total Phosphorus (mg/L) verses flow (cfs) at station 18759, Reese Creek near FM 2670.

Analysis of 24 HR DO Sampling

As mentioned in the project overview, the collection of 5 24-Hr DO samples at North Fork Rocky Creek (station 18334) was added to the project in mid-2018. North Fork Rocky Creek was a part of a special study conducted by TCEQ in 2009. TCEQ evaluated sources of oxygen-demanding materials and their impacts on dissolved oxygen in the creek. In addition to the collection 24-hour dissolved oxygen data over a two-year period between August 2002 and September 2004, biological data was collected. Data indicated that it supports a relatively healthy biological community, better than that which would be expected based on the results of the dissolved oxygen monitoring. In 2010, the TCEQ adopted revised, site-specific standards for dissolved oxygen in Rocky Creek.

Although the standards were adopted (Figure 26), no additional data had been collected within the segment to be used in assessment. Project partners were able to reallocate funds that had been earmarked for biased flow samples to allow collection of 24-Hr DO samples to be used in future assessments. Table 6 is a summary of the 5 sample events collected during the project.

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Chapter 307 - Texas Surface Water Quality Standards
Rule Project No. 2016-002-307-OW

SEGMENT	COUNTY	WATER BODY	ALU	DO	DESCRIPTION	ADDITIONAL SITE-SPECIFIC FACTORS
1217	Burnet	North Fork Rocky Creek	I	4.0	Intermittent stream with perennial pools from the confluence with South Rocky Creek upstream to its headwaters approximately 11 km west of US 183	A 24-hour average DO criterion of 2.0 mg/L and a 24-hour minimum DO criterion of 1.0 mg/L apply when stream flows are below 1.5 cfs.

Figure 26 TCEQ's site specific standards for North Fork Rocky Creek.

Table 6 Summary of 24-Hr DO sampling on North Fork Rocky Creek (station 18334).

Station 18334		Flow	DO			Specific Conductance			Temp			pH	
Deploy	Retrieve		Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max
10/10/2018	10/11/2018	0.01	0.4	3.2	1.4	516	530	522	19.2	21.9	20.6	7.5	7.5
01/08/2019	01/09/2019	36	9.6	10.3	9.8	595	611	606	12.5	14.6	13.5	8.2	8.2
03/18/2019	03/19/2019	12.3	8.5	10.7	9.3	598	605	602	14.4	18.3	16.0	8.0	8.1
05/16/2019	05/17/2019	19.7	7.5	8.4	7.8	563	570	566	21.4	24.8	22.7	8.1	8.2
07/09/2019	07/10/2019	2.7	4.5	7.6	5.7	544	566	557	26.5	30.4	28.1	7.7	7.9

Conclusion

Most stations saw an upward trend in pollutants with an increase in flow, which may occur in a watershed that is primarily rural, with few direct discharges to the system. In the earlier project, *Surface Water Quality Monitoring To Support The Implementation Of The Lampasas River Watershed Protection Plan*, TSSWCB 13-09, there was some concern early in the project about lack of flow at stations 15762 (Lampasas River at US HWY 84) and 15770 (Lampasas River at CR 2925). After consulting with project partners, the decision was made to not move any of the monitoring stations. Those same concerns carried throughout the early part of this project as well. However, these two sites consistently had higher concentrations of E. *coli* during the sampling events than their downstream counterparts.

Data collected from the Sulphur Creek tributary showed interesting trends. During routine sampling events, E.*coli co*ncentrations were very similar moving from upstream to downstream (upstream: 18782, middle: 15781, and downstream: 15250); the geomeans were 50 cfu/100mL, 57 cfu/100mL, and 46 cfu/100mL, respectively. These geomeans are well below the state standard at each station. However, there is a noticeable difference in the geomeans of six samples collected during biased flow events, 410 cfu/100mL, 1886 cfu/100mL, 450 cfu/100mL, again, moving downstream. The range of bacteria concentrations in biased flow events at the midstream site, 15781, 370 – 7500 cfu/100mL is much higher than the other two sites (42 – 6000 cfu/100mL at 18782 and 69 – 5800 cfu/100mL at 15250). This increase in concentration at 15781 is also seen when looking at the geomean of all 31 samples collected with a geomean of 113 cfu/100mL verses 75 cfu/100mL and 71 cfu/100mL at 18782 and 15250, respectively.

The confluence of Sulphur Creek with the Lampasas River is located between two mainstem sites, Lampasas River at FM 2313 (16404, upstream of confluence) and Lampasas River at US HWY 190 (11897, downstream of confluence). The geomean of E. coli concentrations decrease moving downstream from 16404 to 11897, from 60 cfu/100mL to 25 cfu/100mL, respectively, suggesting the Sulphur Creek inflows dilute the mainstem concentrations during routine sampling conditions. This is to be expected, during drier periods as Sulphur Creek benefits from discharge from natural springs as well as constant discharge from a newer wastewater plant.

However, during biased flow events, the opposite is true, with geomean concentration (six samples) of 940 cfu/100mL at 16404 and 1135 cfu/100mL at 11897.

In summary, TSSWCB Project 16-06 has been completed and was essential to the continued water quality monitoring for the Lampasas River WPP. Early water quality data was presented to stakeholders. Results will be communicated during the next Partnership meeting. While implementation of WQMPs did not start until mid-2015, this water quality dataset provides the foundation for a robust dataset to monitor for trends and changes in water quality as we move forward.

TSSWCB project 19-54, *Continuation of Surface Water Quality Monitoring to Support the Implementation of the Lampasas River Watershed Protection Plan*, began collecting samples in October 2019 and will provide 14 additional months of sampling at the same 10 routine sites and an additional 5 24-hr DO events at station 18334. Additionally, AgriLife Research submitted a proposal to TSSWCB in 2019 to continue funding the sampling program for an additional 2 years.